

Bus Transportation Analysis for a Changed Start Time in the Millbury Public Schools

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Abstract

The Millbury Public School System is examining the feasibility of later school start times for their adolescent students. Busing transportation is frequently cited as the major logistical set back in this change. This study analyzes four different potential transportation strategies to help guide informed decision making when determining busing during this district wide adjustment. The four options identified were: *swapping* start times among schools, *pushing* all start times later, *reducing* the number of iterations a bus takes, and purchasing additional buses to allow the high school to start at the *same* time as another school.

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Executive Summary

Complications of busing logistics have long been the counterargument for school districts being unable to implement later start times for their adolescent students. The National Sleep Foundation advises that to better align with their natural biological clocks, instructional learning in the classroom for adolescents should not begin prior to 8:30 a.m.

This study addresses four potential solutions for bus transportation that would allow the Millbury Public School District flexibility in permitting the Millbury Junior Senior High School the capability of a later start time. The major concerns for the four investigated scenarios was the feasibility of implementing the option, and the overall financial impact the option would have in comparison to the district's current transportation budget.

Bus companies operate with a tiered route and a tiered pricing system. The more iterations that a bus completes, the cheaper it is per run for the district. The Millbury Public School district currently runs ten regular size buses and one mini bus on three iterations, one iteration to each school. Each of these buses have a set cost per day per bus. The district also runs a mini bus for special education needs for each school.

The four scenarios investigated were developed in collaboration with Mr. Gregory Myers, Superintendent of Schools, and Mr. Richard Bedard, School Business Manager. They include swapping school times, changing the start times of all schools, removing bus iterations, and adding additional buses. A brief summary of each is discussed below.

Investigated Scenarios

The first scenario, called the Swap option, is the idea to simply interchange the start and end times of Millbury Jr./Sr. High School (grades 7-12), and the Raymond E. Shaw School (grades 4-6). This allows monetary costs to basically remain the same, and routes to also remain the same. However, when doing the analysis, it was discovered that simply switching start and end times does not work with the current bus routes. Only 36% of buses would be on time in the afternoon to pick up high school students. To make the Swap option doable the high school would need to be granted a 10-minute later start in the morning than Shaw currently has. This would make Shaw's new time 7:40 a.m. to 1:57 p.m. and the Millbury Jr./Sr. High School run time from 8:20 a.m. to 2:38 p.m. Elmwood would remain the same.

The second scenario, known as the Push option is pushing the start and end times of the school day back by an optimal amount of time. This is similar to how the school district currently runs delays due to inclement weather. The costs and routes remain the same in this option. Push times of 20, 30 and 50 minutes were investigated. With the 20-minute push, the earliest pickup time would be 6:54 a.m. and the last drop off would be at 4:09p.m. For the 30-minute push, the earliest pick up would be at 7:04 a.m. and the latest drop off would be at 4:19 p.m. Finally, for the 50-minute push option, the earliest pick up would be at 7:24 a.m. and the last drop off would be at 4:39 p.m.

The third scenario, known as the Reduce option, reduces the current three-tier bus route to a two-tier bus system. This removes one iteration of the current bus route,

resulting in combining students in kindergarten through sixth grade on the same bus. The first iteration continues the same routes that the high school currently uses. The second iteration requires 12 buses and includes stops at both Shaw, Elmwood and additionally the Assumption School when needed. There is an approximate 2% increase in price for this option. Although the routes may be slightly longer for the second run, it does cut down on the overall time of the system. All 12 buses, all newly created, are scheduled with at least 94% capacity. The district's current ridership numbers suggest that only 81.5% of Shaw students and 61.4% of Elmwood students assigned to their bus routes utilize the system, therefore it is highly unlikely that buses would be anywhere close to maximum capacity.

The final scenario, known as the Same option allows Shaw and the high school to start at the same, or similar times. This would require the buses to be shared between the two schools or to purchase an additional ten full, and one mini bus for the system. The same bus option is similar to Reduce, but geographically and politically would see more difficulties. The addition of extra buses would require an approximate 80% increase in the current everyday transportation budget.

Brief Conclusions

The Swap, Push, and Reduce are all feasible options for the District to pursue. Contrarily, Same requires a significant increase in the budget that may be more useful allocated elsewhere.

Swap provides a way to give junior/high school students additional time in the morning, without jeopardizing the time students from Elmwood (grades preK-3) would get home. It does however, require students attending Shaw (grades 4-6) to be awake earlier. This solution may also demand additional resources for aftercare, and for transporting high school students to the Shaw fields after school.

Push provides a way to keep everything the same, but allows a later start time for the high school. The 50-minute push option is not recommended mainly due to the very late start of Elmwood, the late afternoon drop off of Elmwood students, and the impact on afterschool practices and games.

Reduce provides a more adventurous option. Bus routes would be changed, operation of buses would change, and costs would slightly increase. However, this is not completely revolutionary to the busing world, as Northbridge and Auburn currently do this for their elementary schools. Tantasqua Regional similarly utilizes this method for their middle and high schools. This option allows for start times that are no more than a 5-10-minute difference between Shaw and Elmwood. The average time for each route is between 27 and 29 minutes, which is comparable to the current route times for Elmwood individually. The greatest amount of time it would take a bus from the high school to its first stop is nine minutes. A general approximation is for Shaw to begin 35-40 minutes after the high school and Elmwood to begin around 45-50 minutes after the high school. Shaw currently starts 30 minutes after the high school. and Elmwood currently starts 1 hour and 13 minutes after the high school.

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1. Introduction

Over the past several years, the recommendation that adolescents should start their school days later has been at the forefront of school districts across the United States of America (Breus, 2018). The question that often arises in these communities is how to implement this recommended change. There is an overwhelming amount of biological evidence regarding the adolescent's natural body cycle to push these discussions. When children begin puberty, their biological clock develops a preference for evenings. This preference continues through adolescence, as a typical adolescent body does not begin to produce melatonin, the body's sleep hormone, until 11 p.m. and it often lasts until 8:30 a.m. For this reason, an adolescent waking up at 6 a.m. to attend class has been compared to the equivalent to the biological clock of an adult waking up at 4 a.m. Due to this biological shift it is predicted that adolescents might be losing as much as two to three hours of sleep per night during an average school week. This is a concern because sleep helps the adolescent brain develop properly. The National Sleep Foundation recommends that adolescents, ages 14-17, need eight to ten hours of sleep per night. Sleep deprivation, along with tiredness, can impact a teen's mental health, blood pressure, weight, cholesterol, and insulin resistance amongst other things. (Breus, 2018)

The Millbury Public School System, a district educating students in a small town of thirteen thousand in Southern Worcester County, is looking into the feasibility of switching the start time for their Jr./Sr. High School from 7:40 am closer to the ideal 8:30 am. The Jr./Sr. High School is housed in one building at 12 Martin Street, and consists of students in grades seven through twelve. The other two schools in the town are Raymond. E Shaw Elementary School and Elmwood Street School. Shaw School is located at 58 Elmwood Street and contains students in grades four through six. Elmwood Street School is located next door at 40 Elmwood Street and contains students in preschool through third grade.

The Millbury School Committee wanted to consider the impact a potential change in start times would have on the transportation of students to and from their respective schools. With the help of the Superintendent of Schools, Mr. Gregory Myers, and the School Business Manager of Millbury Public Schools, Mr. Richard Bedard, four different potential transportation options were determined.

The goal of this project was to examine each of the four potential strategies in busing, and to determine the best viable options for implementation in the Millbury Public Schools System. The first scenario examined is labeled as the Swap option. This option simply changes, or flips, the start and end times of the Jr./Sr. High and Shaw, but keeps the same bus routes and the same start/end times at Elmwood. The second scenario, referred to as the "Push" option, pushes all the start and end times of all three MPS schools back an optimal amount of time. The third scenario, known as the Reduce option, reduces the current three-tier bus route to a two-tier bus system. Essentially, this alternative removes one iteration of the current bus route. As a result, grades K-6 would

be combined on the same bus and include stops at both Shaw and Elmwood. The final scenario, labeled as the Same option, would make Shaw and the Jr./Sr. High start and end at similar or the same times. This would either place upper elementary students on the same bus as high school students, or require the district to purchase an additional ten buses.

The Six Sigma approach to problem-solving, called DMAIC, was the main methodology used in completing this project. This allowed the problem to be specifically defined, information to be measured, an analysis of each of the options to be conducted, and the results to discussed with the system's school committee and administrative team. The main strategies used in the analysis step included cost calculations, demand analysis, and transportation routing and scheduling. In addition, pros and cons charts were created individually for each of the four strategies, and compared using scoring matrices. Control was outside the scope of the project and not utilized.

2. Background

This section addresses the background of the Millbury Public School System and their current transportation practices. It also describes routing and scheduling strategies often used for creating bus routes. Additionally, it takes a look at different districts across the country and locally, who have implemented or looked into the feasibility of later start times. Finally, it explains three local school districts and their practices of bus routing.

Schools and Enrollments

Millbury, MA is a smaller, tight-knit community that serves around 1,600-1,700 students in their school district every year. According to the Massachusetts School Building Authority, through the 2025-26 school years the total district student enrollment will stay in this range. For example, the predicted value of the enrollment in this upcoming year (2020-2021) is 1,616, compared to the actual enrollment of 1683 in the 2016-17 school year. In the broad scope of things, it is fair to say that the enrollment will generally be staying the same over the next decade, only decreasing a potential 4% (Enrollment Projection Team, 2017). This study does not include preschool students who would be enrolled in Elmwood, but they will not be utilizing the daily bus system.

In the 2019-20 school year, there were 632 students assigned bus ridership in the high school, 423 students assigned ridership to Shaw, and 482 students assigned to Elmwood. Any students who live within a mile and a half of the high school is considered a walker, and does not ride the bus. Thus, the distribution of total students transported to each school is 632, 423, and 482 (AA Transportation and MPS, 2019). There are no walkers at Shaw or Elmwood Schools. Table 1 breaks down ridership ages per bus, across the 10 buses and 1 mini-bus used in the system.

Table 1: Assigned Ridership Numbers of the Current Buses for the 2019-2020 Year

	BUS 1	BUS 2	BUS 3	BUS 4	BUS 5	BUS 6	BUS 7	BUS 8	BUS 9	BUS 10	BUS MINI		Total Per Grade
High School													
12	10	10	7	6	9	9	10	10	11	7	2		**91**
11	10	10	15	9	13	6	8	9	10	9	3		**102**
10	10	10	8	9	7	8	5	8	9	5	2		**81**
9	10	9	8	13	16	9	7	5	5	15	5		**102**
8	14	14	12	13	9	21	8	7	11	9	3		**121**
7	12	7	18	16	14	14	13	11	17	12	1		**135**
	66	**60**	**68**	**66**	**68**	**67**	**51**	**50**	**63**	**57**	**16**		**632**
SHAW													
6	11	12	7	19	21	13	8	17	16	11	6		**141**
5	11	12	22	17	14	15	15	6	22	12	3		**149**
4	14	8	16	13	22	20	7	6	12	10	5		**133**
	36	**32**	**45**	**49**	**57**	**48**	**30**	**29**	**50**	**33**	**14**		**423**
ELMWOOD													
3	9	12	12	13	10	11	6	8	15	4	4		**104**
2	10	14	12	16	20	14	11	7	20	9	3		**136**
1	12	8	28	10	13	13	6	7	12	10	5		**124**
K	10	12	17	18	12	10	10	5	9	13	2		**118**
	41	**46**	**69**	**57**	**55**	**48**	**33**	**27**	**56**	**36**	**14**		**482**

Another school that Millbury must provide transportation for is the town residents who attend the Assumption School in Millbury. Assumption is a private, Catholic, co-education school for students in pre-school through eighth grade sponsored by the Catholic Parishes of Millbury and accredited by the National Association of Private School (Assumption School, 2016). Millbury residents attending the school in grades K-8 are given the option to be bused via Millbury Public Schools Transportation. These students utilize the third bus route, otherwise known as the Elmwood route. The buses that pick up these students stop at the Assumption School before dropping the remaining students off at Elmwood Street School. In the 2019-20 school year, twenty Assumption students utilized this service. (AA Transportation and MPS, 2019)

All four of these schools have their own start and end times. Millbury Memorial Jr./Sr. High School runs from 7:40 am to 1:57 pm. Raymond E. Shaw Elementary runs from 8:10 am to 2:28 pm. Elmwood Street School runs from 8:53 am to 3:29 pm. Finally, Assumption School runs from 8:30 am to 3 pm. (Elmwood Street School, 2019)

Millbury Public School Transportation Current Finances

Millbury Public Schools currently holds a contract with AA Transportation, for busing through the 2023-2024 school year. This contract is a three-tiered bus contract that allows students to be dropped off at the three schools, along with the Assumption School in the center of Millbury. The contract allocates 10 regular sized school buses, one mini bus, and one special education bus for each tiered route (Ernenwein & Bedard, 2019). In a multi-tier system students are picked up and dropped off at their school before the same buses turn around and do the same to the next school. In this case, students in grades seven through twelve are picked up first and then dropped off at the high school, before the bus goes back and picks up students in grades four through six to drop off at Shaw, and then Elmwood. Utilizing a tiered system of bell times allows the bus company and the school district to maximize the utilization of each vehicle and each employed driver. This overall minimizes total cost for the district. It can be thought of as buying in bulk for the school system. Historically, single-tiered systems occur in more rural communities that have long routes that make it almost impractical to utilize a multi-tiered system. All tier options include bringing students to and home from school, no matter if there are district delays, early dismissals, or half days. In a multi-tier system, there is no additional price whether the entire district has a half day, or just the Jr./Sr. High School, like during final periods. All of Millbury's student buses currently utilize the exact routes for each tier as well. This means that each bus truly retraces its steps three times each morning, and three times each afternoon to get students back home (AA Transportation and MPS, 2019). In addition, once a week the high school offers two late buses in the afternoon – one for East Millbury and one for West Millbury.

Financially, Millbury Public Schools will spend at least $4,545,707 dollars on bus transportation costs in the next four school years (2020-2024). This total includes inflation in the cost for bus transportation each year. Table 2 includes a more detailed breakdown of their current contract. (Ernenwein & Bedard, 2019)

Table 2: Breakdown of Millbury's Current Transportation Contract

	2020-2021	2021-2022	2022-2023	2023-2024
Regular Routes	$411.00	$423.00	$435.00	$448.00
Shuttle Buses	$371.00	$382.00	$393.00	$405.00
Special Education	$480.00	$494.00	$508.00	$523.00
After School, Late	$125.00	$130.00	$135.00	$140.00
TOTAL ANNUAL COST	**$1,087,507.00**	**$1,119,543.00**	**$1,151,939.00**	**1,186,718.00**

Table 2 only includes the basics of the contract, and does not include predicted Athletic and Field Trip Bus costs. The base prices listed in the table indicate the cost that the school district is charged each day, per bus, for it to leave the bus yard. For example, in order to calculate the total cost of the regular buses for the district each year the base price of $411 must be multiplied by 10 buses per day times 182 school days in order to achieve the annual route cost for these ten buses. This total comes to $810,880. The Shuttle, or mini bus, and the special education bus are the sole buses considered in the base price for each day.

Although busing is a costly part of the school's budget, Millbury Public Schools does not require its students to purchase a bus pass, and is not looking to add this option in the future. Therefore, buses must be available for all students living in town to take to and from school. The only exception to this rule is for students living within a mile and a half of the Jr./Sr. High School. In addition, students do not pay a fee to participate in sports, which in other school districts often contribute to their transportation budgets to get athletes to and from sports contests.

AA Transportation

AA Transportation is the school bus company that Millbury Public Schools currently utilizes. Their main office is located at 605 Hartford Turnpike in Shrewsbury, Massachusetts. The company currently services 22 public and private school districts. These include Grafton, West Boylston, Natick, Lexington, Abby Kelley Foster, St. John's, Worcester Academy, Auburn, Leicester, Southbridge, Marionapolis Prep, Wachusett Regional, Leicester, and Spencer-East Brookfield Regional. AA Transportation was founded in 1996 and also offers other services, such as coach buses and limousines. The President and Owner's name is Ron Ernenwein.

In terms of capacity, their full buses hold 77 students and their mini buses hold 29 students. The special education in-district bus holds 3 passengers and includes a monitor. (AA Transportation, 2020).

Strategies for Creating Optimal Bus Routes

Before completing an analysis on ways that Millbury busing might be affected by a potential start time change, it was important to understand how busing works in public school systems and to investigate different communities that have made the switch or investigated making the switch to later school start times.

Routes v. Scheduling

The problem of busing students can be broken down into two major components: routing and scheduling (Chen, Kallsen, & Snider, 1988). The routing problem is concerned with determining the stop-to-stop route navigated by each bus to each school. The scheduling problem is concerned with determining the timing of all the stops for each bus. Routes are typically developed with bus capacity, student riding time, school time constraints and road conditions in mind.

Traditionally, a predetermined computer algorithm is inserted into a program in order to make efficient routes and scheduling. This means that the user of the program does not need to have any knowledge of the layout of the town or expertise in scheduling. The issue arises that with these types of programs is that non-quantifiable factors such as safety, preference and intuition are not taken into consideration (Chen, Kallsen, & Snider, 1988). To mitigate this issue, computer programs give users multiple optimal routes depending on the objective that is set by the user. This allows the user to examine these routes and select what is best for the community.

Constraints are major limiting factors in determining potential bus routes (Chen, Kallsen, & Snider, 1988). For the majority of districts this includes the maximum number of students per bus, the maximum riding time for a single student on the bus (often one-way sixty minutes is the highest), and the time frame that a bus can drop off students at the school. It also includes the largest distance that a student can be required to walk to a bus stop. This metric often fluctuates depending on the age, or grade level of students as well. For example, a student in high school might be okay to walk half a mile to the stop, where as a first grader might only be okay to walk 0.2 miles to the closest stop. In addition, districts tend to want to use the fewest buses possible in order to minimize costs.

Scheduling in rural and suburban school districts differs from urban communities for a few different reasons. The first reason is that these areas have a lower population density which require buses to travel a greater distance per route in order to reach capacity. This also is due to the fact that there are a fewer number of students per stop and more stops per route. In addition, suburban and rural districts are typically not located near many major highways or roadways. This limits the potential routes that buses picking up students in remote areas can use, which often results in multiple buses overlapping on the same roadways.

There are four major categories of school bus stops (Chen, Kallsen, & Snider, 1988). The first is a *populous stop*, which indicates a stop with a large number of students that contributes greatly to total bus capacity. Second, is a *remote stop*, which is a stop that is a considerable distance from the school. Third, is an *isolated stop*. This a bus stop that is adjacent to a shortest route and would not likely be included in any shortest routes. Finally, the fourth type of stop is a *vicinity stop*. These are stops that are closer to the school and are typically interchangeable in the bus that picks up these stops.

In order to schedule a bus route, it is optimal to identify all the needed stops as accurate as possible to the four types of routes. Once this has been done it is best to apply the populous stops to buses first and calculate each bus's total student counts, travel

distances and travel times. Next, routes are started at the farthest remote stops and the shortest routes to the school are selected, through the populous routes when doable. From here it is investigated whether or not there are any isolated stops to these optimal routes. These detours are added into the already determined routes. Finally, the total times, distances, and current bus capacity numbers are calculated and vicinity stops are added to the routes that have capacity remaining. These completed routes are often created in a circular, or loop, pattern to make the final, optimized route. Once a route is determined, the schedule of the route is created to show expected arrival time at each bus stop. This schedule should be within a ten-minute interval of the indicated time (5 minutes before/after) to ensure accuracy (Chen, Kallsen, & Snider, 1988).

In conclusion, routes and scheduling are the two main components of solving the busing problem in school districts. Constraints need to be set, and information must be gathered about each potential stop before routing can successfully take place. Once an optimal route is gathered scheduling of the stops can be generated by GPS data, traffic patterns, and the number of students per stop. All of this data goes into determining the bus routes for a single town's district in the summer before a school year begins. (Chen, Kallsen, & Snider, 1988)

Later Start Times in the United States

Successful Implementations in Cities

Although, there is an overwhelming amount of biological evidence many adults and school systems have been unwilling to immediately jump on the opportunity to change the school start times in their districts. Those districts that have made the leap have found student results to be positive. One of these studies was conducted during the 2016-2017 school year in the Seattle Public School District. This study found that by pushing their high school start time back 55 minutes, students were able to sleep an average of 34 more minutes per night and their grades increased by 4.5%. Following the completion of this study in 2017, the American Academy of Sleep Medicine officially recommended that middle and high schools start no earlier than 8:30 am. This is in agreement with the threshold that The American Academy of Pediatrics has been advising since 2014. (Dreilinger, 2019)

Recently, seven high schools in Minneapolis, Minnesota moved their start times from 7:25 to 8:30 am and studied the impact it had on the students. Overall, the study found that students slept an additional five hours per week, and that enrollment and attendance rates, along with alertness increased. Furthermore, student-reported depression decreased. This type of impact was also apparent in the middle school shift of start times. After the change, students were four times less likely to be tardy and their grades improved. (Dreilinger, 2019)

Difficulties with Switching and How They Can be Addressed

With the overwhelming positive effects that come for the students with later start times, it would be assumed that school systems everywhere would be eager to do so. However, the fact is that school districts across the country are having difficulties

planning and successfully implementing the changes. Schools are a system of many different aspects and not just the school itself. This includes janitorial/kitchen staff, bus transportation, faculty members, extra-curricular and more. The other apparent problem is that faculty and family work routines have become organized around current school times. Changing something that has been cemented in place for generations is a difficult task to begin with, especially with resentment from parents and guardians.

A major issue with changing a start time is that districts often stagger their start times in order to save money on buses, using the tier system. This causes school districts to simply flip the start times of the high school and the elementary school, forcing the younger students to have the earlier start times. This creates a double-edged sword, with parents of both age demographics, complaining. The major complaints for younger students are: having to wait for buses in the dark, the need to move kids to an earlier bedtime, and the logistical challenges of earlier dismissals with family work schedules and not having older kids available to get the younger children off the bus. This causes many families to incur greater costs for childcare, which is not something they want to undertake in order for high school students to get an extra hour of sleep. Also with earlier bedtimes, parents complained that they barely get to see their children after they got home from work. On the other side, high school parents have greater concerns regarding after school activities of their students or part-time jobs to help financially support the family.

The way school districts to attempt and calm the chaos is to be aware that it will happen and to prepare for the situation. This can be done by having evidence available, and being confident in presenting this information to the community. For example, a district could implement before or after school programs for a reduced cost for low income families, or rearrange the bus routes for elementary students so they do not need to walk long distances to their stops early in the morning. It is also beneficial to gradually introduce the change a year or more in advance to get more feedback from the community. This reduces immediate fear and resistance, which could lead to the transition's downfall. In 2017, Boston attempted to try and change start times but it was met with an overwhelming amount of resistance from parents, the city council and local civil rights leaders. The school district was accused of risking the job security of lower income families. The idea to switch start times ended up being annulled, until a couple years later. If Boston had been up front and active with these concerns initially, and released data regarding an analysis of the racial equity and its relationship, the original initiative may have ended differently (Dreilinger, 2019). Once again, by giving advance notice to communities it makes the transitional period longer and therefore less dramatic. Saint Paul Public Schools created a two-year transitional period (from 2016 until 2018) that allowed the community to address necessary concerns and finalize any logistical changes ahead of time. (Dreilinger, 2019)

The final and most important step of the process is that after initial engagement and concerns are addressed, not everyone needs to completely buy-in before the switch. Turner, the chief operations offer of the Saint Paul Public School District expressed that "broad change is sometimes only achievable as a mandate," and that "there's more

experience in actually doing it." Every family organizes their life in different ways, and those current ways are adapted to the current timings. With some planning and resources, it can be adapted to the changed times as well. They can and will adjust. (Dreilinger, 2019)

Later Start Times in Massachusetts

During research, there was an opportunity to explore other school communities in Massachusetts that have gone through the process that the Millbury Public Schools in currently going through (Start School Later, 2020). After looking through the start times for the majority of high schools in Massachusetts, it became apparent that most high schools do not start after 8 am even in the towns that have made their start times later. Millbury currently starts at 7:40 a.m., which is in the middle of start times for the state. School Start Later Inc., a non-profit coalition of health professionals, educators, sleep scientists, parents, student and other concerned citizens that are dedicated to increasing public awareness about the relationship between sleep and school hours, has indicated that Millbury High is in the 63.27th percentile of high school start times in Massachusetts. The average start time in Massachusetts is 7:37 a.m. and the mode start time is 7:30 a.m. To put this into perspective, the national average high school start time is 7:59 a.m. (Start School Later, 2020). A list with some corresponding start times of Massachusetts High schools that begin at or at after 8 am can be seen in Figure 1.

8:00 am	8:05 am	8:10 - 8:20 am	8:30 - 8:45 am
•Arlington •Barnstable •Chelsea •Hanover •Hingham •Lee •Lynn •Marshfield •Millis •Monument Mountain Regional •Needham •Ware	•Medway (8:04) •Cambridge Ringe & Latin •Sharon •South Berkshire	•Swampscott (8:10) •Beverly (8:15) •Holyoke (8:15) •Ashland (8:20) •Duxbury (8:20)	•Westborough (8:30) •Nauset (8:35) •Winthrop (8:35) •Weston (8:45)

Figure 1: Massachusetts Schools Starting at or after 8:00 a.m. (Start School Later, 2020)

However, many other school districts are beginning to look at making the switch. In 2017, Hagan Rivers of Masconomet Regional School district, and an activist for Start School Later, completed a study on the top 50 public Massachusetts high schools ranked by the US News and World Report list (Kelly, 2019). This study found that 6/50 of the districts had already implemented or approved a start time change. Another 32/50 of the districts were actively exploring the opportunity to make the change and were in some phase of the process, while 3/50 districts already start close to 8 am and were not planning to change. Finally, 6/50 of the districts were simply not considering a change at

the time. Since this study was completed in 2017, there is a chance that some of the districts that were in process have changed to implementing a change. The 2017 distribution can be seen in Figure 2.

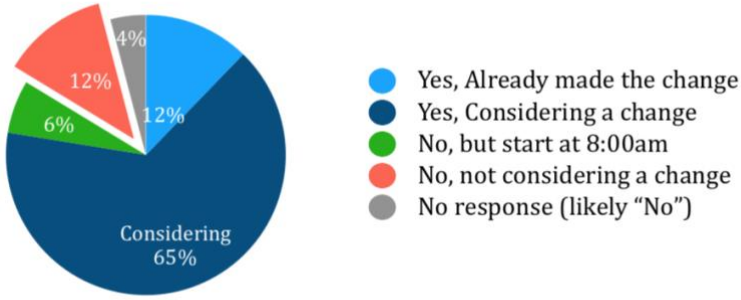
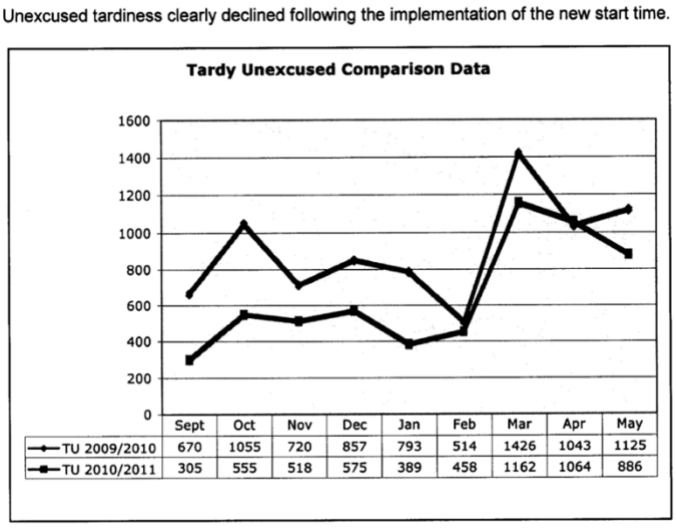


Figure 2: 2017 Polling Data from the National Sleep Foundation Regarding Viewpoint on Later Start Times (Kelly, 2019)

Sharon Public School District

On December 1, 2014 WGBH completed a Special Episode that addressed the need for later high school start times for adolescents (December 1, 2014 Greater Boston Special, 2014). The beginning of this segment discussed how in 2009, Sharon High School made the switch from their 7:25 am start time to an 8:05 am start time. According to Sharon High's principal, there is no going back from this change. He claimed that his students had been noticeably less tardy in the last five years and that they seem to be more attentive in the morning. This statement is aligned with information that the Sharon Start Time Committee released in their status report in June 2011, both in number of unexcused tardies and in student alertness. In the 2010-11 school year Sharon High School had 5,912 tardies compared to the 8,203 tardies in 2009-10. This is a 27.9% decrease between the two years. Also, 42% of teachers believed that students were less sleepy in the morning. In their report, Sharon Public Schools also addressed the public's feelings about the change. According to their report, students in each grade at the high school found the new start time to be a positive change more frequently than they found it neutral or negative. In regard to parent feedback, 63% of parents cited that they had no problems are issues with the new start times, whereas 25% reported negative feelings and 12% neutral. Furthermore, 20% of parents and 53% of students indicated that the impact that this new schedule had on sports was an issue. This concern was investigated by Sharon's Athletic Department with other schools that had



	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
TU 2009/2010	670	1055	720	857	793	514	1426	1043	1125
TU 2010/2011	305	555	518	575	389	458	1162	1064	886

Figure 3: Sharon High School Tardiness Graph, Shows Before and After Adjusted School Start Times

pushed for later start times, and they all experienced this type of rush and crunch time. No school district at the time of the study had created a way to limit this impact. In addition, 33% of faculty found it more difficult to provide extra help to students due to the later release time and teachers having less time before they had to leave to tend to personal outside commitments; 36% of students agreed with this.

Along with these concerns it is important to understand that a major compromise was made in order to allow Sharon High School to begin at 8:05 am. The middle school was required to start at the earlier time because the buses service all of the district's schools. This supports the ongoing problem with managing transportation in school systems looking into making the switch (Ellement, 2009). Mary Hanmaker, the founder of the Massachusetts chapter of Schools Start Later Inc., admitted that "Transportation issues are one of the most difficult, if not the most difficult." This was in agreement to Former Assistant Superintendent of Weston Public Schools, Cheryl Maloney, when she was discussing difficulties of making the switch. Maloney emphasized that "problems with transportation have been the logistical nightmares." Hanmaker acknowledged the challenges but insists they are not "insurmountable." (December 1, 2014 Greater Boston Special, 2014)

Weston Public School District

During the 2018-19 school year, Weston Public Schools switched to later start times for their middle and high schools (Midge & Committee, 2017). They made the decision to switch their school times to 8:45 a.m. to 3:15 p.m., and make the times of their elementary schools from 8 a.m. to 2:20 p.m. (Weston Public Schools, 2018). The logistics of transportation for Weston are made even more difficult due to METCO students attending Weston schools. METCO stands for the Metropolitan Council for Educational Opportunity, and is a voluntary school integration program that was founded in 1966 during the civil rights era. Students of color from Boston are bused to school districts outside of the city in order to give these students different opportunities and promote diversity in the schools (METCO, 2020). With the new change middle and high school students have their first pick up at 8:05 a.m. and are picked up by buses at the schools at 3:20 p.m. METCO students had their first pick up between 6:50 and 7:05 a.m. Elementary schools in Weston picked up the first stop at 7:05 a.m. and for METCO students between 6:10 and 6:30 a.m. After one year of implementation, statistics were released in the news concerning feedback about the change. Overall, 53% of faculty, 69% of students and 81% of parents found the later start times to be positive. However, there was a major issue in the end of the day. The largest issue was the need for students to be released early in order to make it to athletic contests; 89% of faculty perceived a negative impact for these early dismissals (Wyner, 2019). A committee was expected to be established in Spring 2020 to address these issues (Start Time/Scheduling Innovation Steering Committee, 2018).

Nauset Regional School District

Nauset High school implemented a later start time, by over an hour, during the 2011-12 school year. The school day now begins at 8:35 a.m. for students. Over the first semester Nauset found tardiness decline by 30%. School Principal Tom Conrad, noted that students seemed more relaxed when they get to school and students do not seem to be rushing to get to class within seconds of getting to school. They also found an increase in overall first semester grades, and a substantial decrease in number of suspended days in the first two months from 166 days to 19 days. Initially, school officials predicted that this change would save the district over $91,000 on bus transportation costs. However, according to the business manager these savings might be much lower because of the need to add buses back to avoid long waits for middle school students in the afternoon. Another implication of the change has been the increase in tardiness and absent students in the middle and elementary schools. The middle school start time was moved thirty-minutes earlier to 8:30 a.m. and elementary schools were moved 15 minutes earlier to 7:45 a.m. At the time of the study school administration predicted that this could just be an adjustment issue with families developing their new routines. (Fraser, 2010)

Local School Start Time Studies

In order to know what might work best for Millbury, it was also critical to look at school districts surrounding the town. This analysis allows for a more relatable comparison for the district.

Westborough Public School District

Beginning in Fall of 2018, Westborough's school district decided to make a switch to their school start times. Westborough has 6 schools and utilizes a 3-tier, 20 bus system. Before the switch Westborough High School (9-12) and Gibbons Middle School (7-8) ran from 7:30 a.m. to 1:57p.m., Mill Pond School (4-6) ran from 8:08 a.m. to 2:25 p.m., and the three K-3 schools ran from 8:50 a.m. to 3:05 p.m. The high school and middle school are one tier, Mill Pond is another tier, and finally the third tier is all of the elementary schools (School Start Time Committee (Westborough), 2017). The district decided to utilize a swap option between its first and second bus tiers. Therefore, Mill Pond moved to 7:45 a.m. to 2:02 p.m. and the high school and middle school to 8:10 a.m. to 2:37 p.m. The third tier remained the same. The School Start Time Committee came to this recommendation because it had a manageable or no financial impact, it limited potential negative impacts, and it achieved meaningful sleep opportunity for those high school and middle school students. This option was preferred over the push by 20-minute option because there was no time change on the PreK-3 students, it increased the route efficiencies for the district, and it allowed for a better entry/dismissal procedure at Mill Pond. Prior to this change the Mill Pond School bus cycle required the students to wait on buses in the morning before entering the school, and wait 25 minutes for the buses in the afternoon to get back from across Westborough. School Committee chair person, Nicole Sullivan, told the local newspaper that, "The Mill Pond issue is something that I've gotten questions from parents about for years" (Godfrey, 2017). Therefore, the time

switch solved the sleep problem for their adolescent students and improved their busing efficiency at Mill Pond. Although these were improvements, the School Start Time Committee did acknowledge the fact that the change is logistically difficult and no single option works best for everyone. The committee had to look at the situation holistically and do what was best for the greatest number of students, families and faculty – without completely hurting another party. (School Start Time Subcomittee Westborough Public Schools, 2017)

Grafton Public School District

Grafton Public Schools looked into switching their start times within the last couple of years, but did not have a successful campaign like some other schools. Grafton schools had worked out most of the logistical issues, but what really stopped the change was the community's resistance to the plan. Grafton Public Schools have six schools in total. They have Grafton High School, Grafton Middle School, two upper elementary schools (North Street Elementary School & Millbury Street Elementary School), and two lower elementary schools (North Grafton Elementary and South Grafton Elementary). After investigating four different options to change the start times, Grafton decided to recommend their Tier Reduction Scenario, which would have used a three-tier bus route in contrast to their current four-tier route. This option would have started the middle and high schools at 8 a.m. until 2:30 p.m., then North Grafton Elementary and North Street Elementary School would have been scheduled from 8:40 a.m. until 3:10 p.m. and finally Millbury Street Elementary School and South Grafton Elementary would begin at 9:20 a.m. and end at 3:50 p.m.

This schedule was chosen to give high school and middle school students the maximum benefits of sleeping later, to limit the impact on athletics, to minimize impacts on the elementary schools as much as possible, and to allow for older students to get younger siblings off the bus. It also took into consideration the overwhelming logistical challenge of transportation, and the huge budget portion that it takes from the district. According to the district's research, a 3-tier bus system that allowed parity for all schools was too expensive to consider, and that 40 minutes was the required time between bus routes. Even with this new proposed bus schedule, the overall cost would increase. The current bus route system is a four-tier system that uses 17 buses daily. With the new three tier system, an additional 4 buses would need to have been added for a total of 21 buses. This difference of cost per bus was approximated to be $74,500 dollars, which overall would be an increase in the districts transportation budget of $298,000 per year. (Grafton's Later Start Time Committee, 2019)

Although this plan made sense logistically and biologically for its adolescent students, the community complained of an inequality between North and South Grafton school schedules. It was argued that North Grafton parents would encounter considerably more costs for childcare and lost work time compared to South Grafton parents, due to the more significant time changes proposed for that side of town. North Grafton parents also claimed that their children were being used as a scapegoat for the rest of the district. This is likely because these students need to be up earlier, as the start times between the

two elementary schools is close to an hour. There was also fear that doing this would further place a divide between North and South Grafton. Grafton's Superintendent, James Cummings, indicated that he would like to see the change happen as soon as possible, while also noting that adding additional buses is simply not in the school's budget. Currently, this decision has been paused until focus groups can get together and fix some of the community's issues (Bowles, 2018). Grafton does use AA Transportation like Millbury.

Local School Busing Studies

In addition to looking at local school districts that pursued later start times, it was also critical to research about how other schools close to Millbury currently run their bus systems. What intrigued me about Auburn, Tantasqua and Northbridge was their ability to share the same buses for multiple schools. This was very appealing information to my research due to Shaw and Elmwood being next-door neighbors.

Auburn Public School District

The Auburn Public School District currently uses an 11-bus, 3-tier system very similar to Millbury's current bus system (along with 3 Special Education Buses). Auburn even uses the same bus company as Millbury. The difference comes with the number of schools serviced. While Millbury only services 3 schools with this contract, Auburn services 5 schools. Auburn in addition does charge for buses and requires students of all ages to register. Auburn High School and middle school both use all 11 buses. From here, the buses split to both sides of Auburn. Five buses are used for the side where students K-2 attend Bryn Mawr Elementary, while 6 buses are used for the side where students K-2 attend Pakachoag Elementary. Students from both sides of town attend Swanson Road Intermediate School in grades 3-5. The buses pick up all remaining students (K-5), then bring them to Swanson Road. Once the 3-5 grade students are off the buses, the bus brings the K-2 students to the correct school (Auburn Public Schools, 2019). Although Pakachoag is across town from Swanson Road, the start times between the two schools are still only 10 minutes different, 8:30 am to 8:40 am. (Auburn Public Schools, n.d.). In the afternoon, the same process occurs, students are picked up from Swanson Road before getting the students at either Bryn Mawr, or Pakachoag, before dropping the students off.

Financially, Auburn just went through the bidding process with AA Transportation. For the upcoming year, of their three-year contract, the total price of busing will be $1,179,588.95. This is highly comparable to Millbury's current contract, and Millbury's buses do not travel the amount of mileage that these buses travel (Wirzbicki, 2020). This makes combining routes alluring for Millbury in the future.

Tantasqua Regional School District

Although highly different from Millbury, the Tantasqua Regional School District does utilize a two-school one route system. The Tantasqua Regional School District serves 5 towns by having 5 elementary schools (Brimfield, Brookfield, Holland, Burgess

(Sturbridge), and Wales), one junior high school, and a combined Tantasqua High School and Tantasqua High School Technical School (Tantasqua and Union 61, 2020). Each sending town has its own buses for the elementary students, and combination buses for the students attending "Tantasqua." This includes junior high students, the high school students, and the vocational students (Tantasqua and Union 61, 2019).

In order to understand the drop off system, it is important to understand that the junior high school is across the street to the high school. The technical school is in the same building as the high school. When students arrive to the campus they are dropped off and do a cross-the-road swap. Tantasqua Regional School District has made the decision to purchase their own buses. Therefore, operational costs are not relevant for this study.

Northbridge Public School District

The Northbridge Public School System currently uses 14 buses to get students to and from their 4 schools. They have Northbridge Elementary School (grades PreK-1), Balmer School (grades 2-4), Northbridge Middle School (grades 5-8), and Northbridge High School. The district requires families to register for busing in all grade levels, but following Massachusetts General Law, Section 8, all students K-6 that live at least 2 miles from the school are given free transportation (Northbridge Public Schools Transportation, n.d.). Those above sixth grade are subject to a bus fee.

The district utilizes a 2-tier system for their schools. Out of the 14 buses, 5 buses bring students to the high school and 9 buses bring students to the middle school. This together is one tier. The 14 buses then pick up the K-4 students on the 14 remaining buses. They drop off students at Balmer School around 8:15 a.m. and then swing over to Northbridge Elementary and drop off their students there at 8:25 a.m. (O'Donnell, 2019)

Northbridge Public Schools utilizes the Vendetti Bus Company out of Uxbridge, MA. In FY 2019, the district spent $1,231,599 in busing costs and in FY 2020 they spent $1,296,622. There was a $65,023 contract rate increase in between the two years. (Mckinstry, 2019)

3. Methodology

DMAIC	A3
Define	Clarify the Problem
Measure	Break down the Problem
	Set a Target
Analyse	Analyze the Root Cause
	Develope Countermeasures
Improve	See Countermeasures
Control	Evaluate Results & Processes
	Standardize Success

Figure 4: Breakdown of the DMAIC and A3 Strategies (Liesener, 2013)

The following objectives describe how I gathered the current state of the public schools' transportation system, understood the needs of the school committee and school administration, and utilized different analysis methods in order to draw conclusions about each of the four investigated scenarios for the district.

The overall methodology of this project followed a DMAIC approach. As seen in Figure 4, DMAIC is an acronym for define, measure, analyze, improve and control. The DMAIC problem solving approach originated from Six Sigma, a continuous improvement technique intended to improve business practices by reducing defects in a system (Lean Six Sigma Definition).

An expanded version of the DMAIC process is known as the A3 problem solving approach. A3 is a problem-solving and continuous improvement strategy that is utilized in Lean manufacturing. This strategy allows the problem solver to thoroughly work through the task at hand. These steps can be seen in Figure 4. Therefore, a DMAIC and an A3 approach have similar goals with different mindsets.

Define

To define the problem, it was important to examine both the grand scope of the problem and the specific problem given to me. The big scope of the problem was to allow the district's adolescent students the opportunity to have a later start time in the morning. The more centralized problem within the scope of the current project was to determine the best viable transportation options in order for the school district to have the logistical tools to make the change.

The final problem statement defined was to: Determine the best viable bus transportation options for a later adolescent student start time in the Millbury Public School System.

Measure

Measure gave the opportunity to examine the current problem by investigating it further, by collecting relevant data about the process and the problem. For this project, I was able to investigate the current situation of transportation in the Millbury Public School System, along with best practices of bus routing, and the experience of local towns in their later start time journeys. I also took a deeper look into the bus systems of Millbury's surrounding towns. This process is further explained in Objectives 1 to 3.

***Objective 1:* Research Best Practices of Busing and Later School Start Times in Local Communities and the United States**

By reviewing national, city specific, and local newspapers and district websites, I was able to understand the successes and shortcomings of other districts who went through the process of researching and implementing later start times for its adolescent students.

***Objective 2:* Understand Current Millbury Public Schools Transportation and its Needs**

Through reviewing the Millbury Public Schools Website, talking to Administration, and reviewing data provided to me directly from the school district, I was able to understand the current operations of AA Transportation's buses in regards to the Millbury Public School System. Information investigated included:

- Current Bus Routes and times of stops
- Grades of students at each bus stop
- Financial Information regarding current Bid from AA Transportation
- Bus Reduction Proposal From 2018
- Bid Information for 2020-2024
- Current Assumption Students
- Allocated Bus Counts, and Updated Counts from November 2019 and from October 2017

***Objective 3:* Research Best Practices of School Bus Routing**

Through reviewing expert literature and sample routes, I was able to learn about the best practices for designing and developing bus routes. This included the process taken in assigning students to bus stops, and stops along different routes.

Analyze

The analyze step gave me the opportunity to develop a deep dive into each of the four possible strategies using the knowledge previously collected. This allowed me to investigate the feasibility of each option, examine the different effects of each option, and gain a complete understanding of what an implementation of the potential changes would be. Analyze correlated greatly with Objective 4.

***Objective 4:* Conduct an Analysis of each Alternative**

After looking at the current data at hand and discussing possible options for a time switch with the administration, four strategies were identified for investigation. These scenarios were each given a name to simplify overall discussion. As mentioned previously these scenarios are known as: Swap, Push, Reduce, and Same. Analysis approaches included cost calculations, demand analysis, and a transportation routing and scheduling problem.

The analysis of each scenario addressed the following areas, as appropriate:

Explanation of Situation
This description clearly indicated what the observed scenario was including any logistical information required to understand the investigation.

Overall Financial Impact of Option
This analysis highlighted any expected changes in the schools current busing costs that would be required in order to implement this scenarios' change. Any additional buses, routes, or tier information was taken into account for this portion.

Pros / Cons Table
A table of pros and cons was developed that listed any societal, financial, or logistical benefits or drawbacks of the proposed scenario to the Students/Faculty/Administration, which are not directly reflected in the routes of the buses or the timing and logistics of busing.

Transportation Concern
The major aspects of transportation that are critical within the research for the selected scenario were investigated. This could have depended on feasibility, money, drop off and pick up times for certain routes or schools, amongst other things.

Modified School Times
A table was included that stated the new proposed school times under the proposed scenario. When needed, the table included multiple proposed times, or an original time and a revised time.

Analysis Methodology
The analysis methodology explained the research methodology that was completed in order to gather the information needed for the given scenario. This gives the user of the report information on how to repeat or modify the study in the future.

Findings
This information is displayed either in the results itself or in the appendices. The material included tables of data results, calculation information, and routes created to provide supplemental information for the report.

Conclusions
The conclusions for the given scenario addressed main findings, as well as important positives and negatives of each option. Political and social concerns were met with data analysis findings to give an entire system outlook.

After examining each individual strategy, a scoring matrix was used to numerically compare the pros and cons tables developed in each analysis. Each given category indicated for the scoring matrix (costs, time, amount of change required, effect on morning/after care, athletics, the assumption school, and miscellaneous), was given a rank of 1 to 4. One was the most favorable, and four was the least favorable. By assigning weight value to the categories, I was able to calculate the total scores of the pros and cons tables.

Improve

Improve is where the solution is implemented and verified. Although implementation was outside the scope of this project, I recommended an optimal alternative and received verbal feedback through discussion with school administration and the Millbury School Committee on April 29, 2020. Objectives 5 and 6 explain the steps more deeply.

Objective 5: Recommend a Best Alternative

Once the analysis on each potential scenario was completed, a best alternative based on different criteria was selected. This decision was made by looking at logistical aspects, such as total system time, costs and matrix results, in conjunction with qualitative data listed in the pros/cons tables.

Objective 6: Test Results with School Committee

Because the solutions developed cannot be implemented immediately to measure the success of the study, or ultimately the project, success was defined by presenting the report to Superintendent Myers, Business Manager Bedard, and the Millbury Public School Committee in order to gain valuable feedback and to address concerns.

Control

Control is the step in DMAIC where the solution is maintained, or improved to make the solution the most optimal it could be long-term. Unfortunately, it was not realistic at this point and time to implement any of the investigated strategies. Therefore, control was outside the scope of this project.

4. Results: Four Busing Approach Strategies

This section describes the four analyses conducted for each of the strategy options. Additionally, it contains a scoring matrix that was used to cross compare each strategy numerically.

SWAP Strategy

The Swap strategy simply changes the start and end times of Millbury High school with the current start and end times of Shaw Elementary School. This allows the bus routes to remain the same, and for Elmwood start and end times to remain the same. The daily operational costs would remain the same as the current contract.

Table 3: Original Proposed Start Times for Swap Strategy

	Original Proposal - Does Not Work
MHS/MJHS	8:10 a.m. – 2:28 p.m.
Shaw	7:40 a.m. – 1:57 p.m.
Elmwood	8:53 a.m. – 3:29 p.m.

When conducting this analysis, the first issue that needed to be addressed was if the new time frame was feasible. The new proposed times are seen in Table 3. In general, I discovered that Shaw routes are often longer than the High School routes. Routes could be adapted in the morning for this issue by starting the routes earlier than is currently the case. However, with the amount of time allocated in the afternoon for drop off (approximately 30 minutes), only 4 out of 11 buses could get to the high school by 2:28 p.m. This converts to 36% of the total system. After conducting this analysis, I calculated the lead times for each bus that could make it on time. My initial idea was that I may be able to rearrange bus routes to get more buses able to make it to the high school by 2:28 p.m. Unfortunately, no bus had a greater lead time than 3 minutes. The 4 buses and their lead times can be seen in Table 4. It is very important for the high school buses to be at the school for 2:28p.m. because when the final bell rings in the high school students are given the freedom to go to their lockers and head home or to their after-school activities. Therefore, buses are all released at once and multiple buses cannot be unavailable for the time of release.

Table 4: List of Buses that Could Make It to The High School in Afternoon for Original Swap Option with Arrival Time

BUS NO.	Time Arrived	Lead Way
3	2:25	3 min
4	2:27	1 min
6	2:28	0 min
8	2:26	2 min

After realizing that the originally proposed swap option would not be a feasible strategy, I brainstormed alternatives to salvage this scenario. While analyzing the time of arrival for each bus at the high school, it became clear to me that if given a 10-minute buffer period all of the buses could make it to the high school by 2:38 p.m. The time each bus could arrive at the high school can be seen in Table 5.

Table 5: Earliest Time Each Bus Could get to the High School with 10-minute Buffer

Bus	1	2	3	4	5	6	7	8	9	10	Mini
Arrival (pm)	2:37	2:37	2:25	2:27	2:33	2:28	2:31	2:26	2:33	2:30	2:32

In order to maintain proper school time, I knew that I needed to also alter the start time back by 10 minutes. This extra time in the morning is beneficial as well. Students at the Jr./Sr. High School are currently given time to go to their lockers, go put away bags in the locker room and band rooms, etc., before heading to their homerooms (currently known as their Common Directed Study, or CDS). Without the extra time in the morning some buses would arrive close to 8:10 a.m. which would not allow these student time to do what they need to do in the morning. The new proposed times are shown in Table 6.

Table 6: Comparative of Original Proposed Time and Modified Proposal Time for Swap

	Original Proposal - Does Not Work	**Modified Proposal – Success**
MHS/MJHS	8:10 a.m. – 2:28 p.m.	8:20 a.m. – 2:38 p.m.
Shaw	7:40 a.m. – 1:57 p.m.	7:40 a.m. – 1:57 p.m.
Elmwood	8:53 a.m. – 3:29 p.m.	8:53 a.m. – 3:29 p.m.

Given this analysis, this switch was compliant with both the high school and the Shaw school; however, I needed to check that this change was not going to impact Elmwood Street School. After completing a thorough morning and afternoon analysis it was discovered that all students could get to Elmwood before 8:53 a.m. and the bus would arrive at Elmwood on time in the afternoon. Due to this analysis, it is also fair to say that the drop off for the Assumption School would remain the same as it is now, with zero to minimal effect. The times for the Elmwood buses can be seen in Table 7.

Table 7: Arrival Times to Elmwood in Morning and Afternoon

Bus	1	2	3	4	5	6	7	8	9	10	Mini
Arrival (am)	8:34	8:35	8:24	8:18	8:28	8:27	8:49	8:38	8:18	8:30	8:22
Arrival (pm)	3:10	3:18	3:10	3:00	3:02	3:00	3:15	3:06	2:53	3:11	3:08

To finalize the Swap analysis, I created a table that demonstrates the pros and cons of the option. Each category was additionally scored a 1 through 4. In this scoring, 1 was no impact/change, 2 was minimal impact/change, 3 was mild impact/change and represented significant impact/change, based on my assessment of the impact.

Table 8: Pros/Cons Chart for Swap

	Pros	Cons	Score
Costs	• Approximately the same	• Additional bus may be required to get students to Shaw after school	2
Time	• Actual class time would not begin before 8:30 a.m. due to CDS at High School	• Shaw students getting picked up earlier than High School Students are now. • They also get home earlier	3
Amount of Change Required	• Bus routes remain the same	• Problems if older student needs to get younger student off bus • Parents may express concern on impact it has on activities/after school job. • Shaw Students Up Earlier	2
Effect on Morning/After Care		• May see an increase in after care needs at Shaw	1
Athletics	Pushing MHS back by only 40 minutes makes it easier on Athletics to • Keep Sports Practices almost the same • Games at 3:30 still	• Bus might be required to get students to Shaw (fields/gym)	2
Assumption School	• No Impact – still would be on the Elmwood Route		1
Miscellaneous		• Longer delay for parents between Shaw/Elmwood drop of and pick up. • Teachers less likely to stay longer into evening for extra help.	1

PUSH Strategy

The Push strategy involves pushing the start and end times of all the schools back a set amount of time. The optimal amount of time to push back the start time of the high school would be 50 minutes. This makes the start time of the high school 8:30 a.m., which perfectly coincides with The National Sleep Foundation's research. However, I was not convinced that pushing all schedules later by 50-minutes would be doable. Therefore, a 20-minute, 30-minute, and 50-minute push was investigated. The new proposed start and end time for each of these options can be seen in Table 9.

Table 9: Proposed Start and End Times of Each School under Push Strategy

	20-Minutes Push	30-Minutes Push	50-Minutes Push
MHS/MJHS	8:00am - 2:17pm	8:10am - 2:27pm	8:30am - 2:47pm
Shaw	8:30am- 2:48pm	8:40am- 2:58pm	9am - 3:18pm
Elmwood	9:13am - 3:49pm	9:23am - 3:59pm	9:43am - 4:19pm

After Completing the full analysis, I was able to focus on the earliest pick-up and the earliest drop off times for each school, and the entire bus system. For the 20-minute push, the entire system ran from 6:54 a.m. until 4:09 p.m. For the 30-minute push, the entire system ran from 7:04 a.m. until 4:19 p.m. Finally, for the 50-minute push the system ran from 7:24 a.m. until 4:39 a.m. A breakdown of each school can be seen in Table 10.

Table 10: Earliest Pick-Up and Latest Drop-Off Times for Each Push Scenario

20 Minutes	Earliest Pick Up Time	Latest Drop Off Time
JR./SR. High School	6:54 AM	2:53 PM
Shaw Elementary	7:40 AM	3:31 PM
Elmwood Street School	8:25 AM	4:09 PM

30 Minutes	Earliest Pick Up Time	Latest Drop Off Time
JR./SR. High School	7:04 AM	3:03 PM
Shaw Elementary	7:50 AM	3:41 PM
Elmwood Street School	8:35 AM	4:19 PM

50 Minutes	Earliest Pick Up Time	Latest Drop Off Time
JR./SR. High School	7:24 AM	3:23 PM
Shaw Elementary	8:10 AM	4:01 PM
Elmwood Street School	8:55 AM	4:39 PM

In my opinion, the 50-minute option seems unachievable for multiple schools. With the 50-minute switch, athletics would run into many problems, especially regarding after school games. The 50-minute switch is also not ideal for the youngest students. Younger students often are up earlier in the morning, and making them to wait to almost

9:45 a.m. to start their school day is unfair to them. In addition, having students getting home so late in the afternoon really minimizes the amount of time that these younger students have with their families before heading off to bed. Morning care would also need to be highly expanded for younger students with the 50-minute option.

Continuing the analysis, I looked into which buses were causing the system to run longer to see if load could be distributed elsewhere. Other than Bus 1, which is a repeat offender, all of the other latest and earliest runs are completed by different buses. Bus 1 does make sense as the longest route for drop off from the elementary schools in the afternoon because it is the route that starts the farthest point from the schools and loops back towards the center of town (Grafton Road to Riverlin Street). The buses are shown in Table 11.

Table 11: Earliest Pick Up and Latest Drop Off by Bus per School

	Earliest	Latest
JR./SR. High School	7	Mini Bus B
Shaw Elementary	2	1
Elmwood Street School	6	1

To finalize the Push analysis, I created a table that demonstrates the pros and cons of the option. As before, each category was additionally scored a 1 through 4. A reminder that 1 was no impact/change, 2 was minimal impact/change, 3 was mild impact/change and 4 was significant impact/change.

Table 12: Pros/Cons Chart for Push

	Pros	Cons	Score
Costs	• Remain the exact same		1
Time	• Actual class time would not begin before 8:30 a.m. due to CDS at High School • 20 or 30 minute push is enough	• Elmwood might run into more commuter traffic in afternoons. • Families have less time with younger students before bed time. • Elementary school students often wake up earlier in the morning, therefore they would be waiting around for school more	3
Amount of Change Required	• Bus routes remain the same; at altered time • Older students can get younger students off bus • Same routine	• Parents may express concerns about the impact this change would have on after school activities or jobs. • Could have an effect on preschool hours of operation for half day programs.	1
Effect on Morning/After Care	• Might minimize students needing aftercare	• Parents may complain about morning child care. Current program may need to be expanded	2
Athletics	Pushing MHS back by only 20 - 30 minutes makes it easier on Athletics to • Keep Sports Practices almost the same • Games at 3:30 still Students can take bus to Shaw after school	• Sports would be highly impacted in the 50-minute situation. No other school in SWCL has a schedule this different.	1
Assumption School		• This would affect which bus students who attend the Assumption School would be on. With the 50-minute option this would result in Kindergarteners potentially on buses with Seniors.	2
Miscellaneous		• Teachers less likely to stay longer into evening for extra help. • Might meet resentment from teachers with children in other districts.	1

REDUCE Strategy

The Reduce strategy is the most complex scenario. It removes one iteration of the current bus route. This combines grades K-6 on the same bus, and includes stops at Shaw, Elmwood, and the Assumption School when needed. The objective of this scenario is to reduce the total time of the system. This translates in layman terms to decreasing the amount of time that it takes all the buses to pick up all the students and bring them each to their respective schools. By reducing the total system time, the high school can be pushed back, but it wouldn't push back the other schools as much as in the three-tier system.

In order to determine how this option would work I needed to ensure that every student has a seat on a bus. Initially, I tried to make this simple by just picking every student at both schools up on the same run. I quickly found that there were only 4 buses in which this worked… and they were all on the West side of town. Therefore, I needed to start almost from scratch to develop new routes. I did keep the same bus stops as currently indicated by the bus company.

The objective of creating the new routes was to simply show that it can be done, and not necessarily to prove that the routes developed must be implemented. Often the bus company creates its own routes; however, this analysis demonstrates for the district that they can require the bus company to only utilize the minimum number of buses. To identify that minimal number, I utilized the methodology of sectioning out the town (available in Appendix 8.8), and working from the outskirts of town inward (Chen, Kallsen, & Snider, 1988). Even though Shaw and Elmwood are located on the west side of town, they are mostly centralized. Therefore, all buses from the east need to head through the center to drop off the students. Likewise, buses on the west side need to drive towards the center to get to the schools. This allowed me to have buses with remaining capacity pick up students at the remaining stops on their way to the schools. I was able to get every student in K-6 on 12 buses, which is 1 ½ more buses than the district currently uses. This increase in buses, with a reduction of tiers totals 11 buses operating with 2-tiers and 1 bus operating with 1-tier. Financially, this results in a $15,581.02 approximate increase of the daily transportation budget in a year (an increase of 1.9%).

It is important to remember that Millbury currently provides busing to all its residents and that families do not need to pay or register their students to utilize the transportation. Because of this, buses are never at full capacity. According to a 2019 study conducted by AA Transportation, 352/432 students at Shaw took their assigned bus (81.5%) and 321/523 students at Elmwood (61.4%). This means that a route scheduled at maximum capacity (77 students), should only expect 55 students on that bus. This is an approximation of about 71.5% of students.

When creating the bus routes, it came to my attention that East/Central Millbury were going to need more buses than West Millbury. There are more students per space in the east and central areas. This means that often I reached capacity prior to completing an area. East Millbury has all of the major housing developments in town. For example, there is McArthur Drive, Oak Pond Ave, Hayward Glen Drive, LT Haynes Drive, Autumn Gates Circle, Memorial Drive, Paul Revere Village, and Diana Hill Road. When

a bus stops at these stops, they pick up anywhere from 10-18 students at a time. In contrast, in West Millbury most students get picked up door to door, and a bus needs to travel a lot further in order to get a larger capacity of students on their bus. Often the bus also needs to travel down and back on these main roads (e.g., Auburn Road, West Main), in order to minimize crossing required for students (this minimizes time at the stop and maximizes safety for the students). Ultimately, the goal was to minimize the buses required (to minimize costs) by maximizing the capacity (increasing the total number of students on the bus), while also trying to minimize the total time of each route (by utilizing geography).

For each route created, I made an official bus route with complete directions. This documentation shows how many stops there are in the route, the maximum number of students that would be picked up at that stop, and a map of the route. Some stops have letters next to them to indicate points on the map for reference. All of the routes that were developed are presented in Appendix 8.9.

In addition, for every route I calculated a maximum capacity percentage, the approximate time required for each route (allocating between 25 and 30 seconds for each stop; some stops would take longer or shorter depending on number of students getting on and where they are getting on from), the mileage of the route, and the time that it takes the bus to get to each stop from the high school. This information is shown in Table 13.

Table 13: Summary of Each Created Bus Route and their Capacity

Bus #	Capacity Per Bus	Length of Each Bus Route	Mileage of Route	Time to First Stop from High School
1	95 %	31.5 minutes	6.4 miles	9 minutes
2	97 %	27.3 minutes	6.9 miles	8 minutes
3	100 %	28.63 minutes	6.7 miles	5 minutes
4	100 %	18.7 minutes	4.1 miles	6 minutes
5	100 %	29 minutes	6.1 miles	4 minutes
6	99 %	35.2 minutes	8.4 miles	0 minutes
7	96 %	27.77 minutes	6.9 miles	4 minutes
8	95 %	25.08 minutes	5.9 miles	4 minutes
9	99 %	25.08 minutes	4.4 miles	3 minutes
10	94 %	47.15 minutes	12.4 miles	9 minutes / Does Not Apply
11	99 %	33.38 minutes	7.2 miles	4 minutes
12	99 %	32.25 minutes	8.1 miles	6 minutes
Average	**97.75%**	**26. 26 minutes / 28 minutes**	**6.96 miles**	**4.81 minutes**

Bus 10 takes the longest, but has the least number of students onboard. The reason for this is that this route circles Ramshorn Pond (into Sutton), travels down South Oxford Road into Oxford, down Federal Hill Road, travels into Auburn, gets students at Gilbert

Way and West Main, then loops back down to get students on Stone and Stowe Road, before traveling down Carleton Road to the schools. Unfortunately, these student's homes are so secluded that there is no quicker way to get all of these students. For this reason, if the high school were to keep the current routes that it has, Bus 10's route would need to be the bus that does not go to the high school. This way Bus 10 would have the ability to start prior to the others to minimize the total time of the system. In addition, if the district cut down the number of high school buses to 10 (from current 10 ½), then Bus 1 should also be a 1-tier bus to further minimize the overall system time. Bus 1 does not start until Grafton Road, almost directly across from the Mass Pike entrance.

In total, the overall system time would be decreased by approximately 25 minutes. Shaw would have the ability to begin 35-40 minutes after the official start time of the high school, while Elmwood would be able to start 45-50 minutes after. This information is without changing the current high school bus routes. Assumption students may be able to stay on this bus (as currently accounted for), or they may need to sit in the front of a high school bus depending on the decided start time of the high school. There are not a huge number of Assumption students assigned to buses, so an option should likely not be dismissed due to those children.

As in the first two strategies discussed, a pros and cons list was created for this scenario, scoring each using the scale: 1 was no impact/change, 2 was minimal impact/change, 3 was mild impact/change and 4 was significant impact/change. The result is shown in Table 14.

Table 14: Pros/Cons Chart for Reduce

	Pros	Cons	Score
Costs	• Slight Increase in Budget	• Slight Increase in Budget	2
Time	• Much less time for overall system to run. • Actual class time would not begin before 8:30 a.m. due to CDS at High School	• Slightly longer routes for students • Possibility of increased traffic in area	2
Amount of Change Required	• High School Routes can remain the same	• Big Learning Curve • Bus Driver Complaints. • New Bus Routes for younger students • Parents doing pick up at both may become overwhelmed.	4
Effect on Morning/After Care	• High school students can get younger children off bus.	• May see an increase in aftercare needs at Elmwood	1
Athletics	• Minimal impact depending on high school start time.		1
Assumption School		• Would likely have a decent impact	2
Miscellaneous		• Teachers less likely to stay longer into evening for extra help. • Parents may express concern on impact it has on activities/after school job.	1

SAME Strategy

The Same strategy gives the high school free reign and ultimate flexibility in setting its start and end times, by purchasing an additional ten full buses for the system. This analysis is simply financial.

The yearly daily cost for the 2020-2021 school year is $815,542. In order to add 10 additional buses, the capacity used for a high school run, it would cost an approximate total of $8,093.11 per day, or $1,472,946.02 per year. A $657,404.02 increase in the yearly budget for daily transportation correlates to an 80.6% increase in the total budget. This is a major upsurge in the budget, which might be better spent elsewhere in the school district. After making this calculation, further investigation was not seen as warranted.

As completed for the other three scenarios, a table expressing pros and cons of the option was created. Once again, each category was scored, with 1 representing no impact/change, 2 minimal impact/change, 3 mild impact/change and 4 significant impact/change.

Table 15: Pros/Cons Chart for Same

	Pros	Cons	Score
Costs		• 80.6% increase in budget	4
Time	• More time available • Freedom to start High School whenever		1
Amount of Change Required	• Routes can remain the same	• Some Shaw students may arrive home before high school students • Need 10 more drivers • Change of Routine	2
Effect on Morning/After Care			1
Athletics		• Bus might be required to get students to Shaw (fields/gym)	1
Assumption School	• No Impact – still would be on the Elmwood Route		1
Miscellaneous		• Teachers less likely to stay longer into evening for extra help.	1

Scoring Matrix

Utilizing the scores from each strategy's pros and cons table, a scoring matrix was created that provides the ability to translate qualitative data into numerical data in order to compare the options. The scoring matrix is shown in Table 16. To develop the matrix, categories were first defined. The defined categories were the same as the developed pros and cons tables. *Costs* indicated the amount of money that the district was going to need

to spend in comparison to their current spending. *Time* indicated the amount of time that the entire system took. A reminder that the system includes picking up each child from each stop and getting them to the school, or vice versa in the afternoon. If the time was the most optimal it was given a score of 1, if it was significantly longer it would be given the score of 4. The *Amount of Change Required* judges the learning curve that the district and families would need to go through with this change newly made. *Effect on Morning/After Care* indicated the amount of increase that would be need to be implemented on either end of the day in order for families to sustain the new time changes. *Athletics* indicated the impact that the given strategy would have on athletics, including busing to fields and the impact made on after school practices and games. *Assumption School* indicated the result it would have on busing those students to the Assumption School. Finally, *Miscellaneous* encompassed any other things that did not fit into the other categories and if any of them were of high importance.

A second decision that must be made is to assign importance weights to each category. In Table 16, I weighted costs as 60% important because I felt it would be counterproductive to spend a lot of money to make a change. I selected time as 20% important. When optimizing any transportation problem, one goal is typically to reduce the amount of time that is needed. This also helps in the district by restricting the latest time that students may possibly get home in the afternoon. I gave the amount of change that is required a 10% weight. Although a learning curve is important up front, in order to set everything up and to get people on board, once the transition is made it is not as important. Finally, I scaled the remaining categories each at 2.5%. Although these categories are all important in the entirety of the systematic problem, they do not heavily contribute to busing enough to greatly impact the final decision. Due to scoring definitions, the lowest score is the most optimal decision by the given characteristics.

Table 16: Complete Scoring Matrix

	SWAP	PUSH	REDUCE	SAME
Costs (60%)	2	1	2	4
Time (20%)	3	3	2	1
Amount of Change Required (10%)	2	1	4	2
Effect on Morning/After Care (2.5%)	1	2	1	1
Athletics(2.5%)	2	1	1	1
Assumption School (2.5%)	1	2	2	1
Miscellaneous (2.5%)	1	1	1	1
SCORE	2.125	1.45	2.125	2.9

Given this matrix, the Push Option is the best. This makes sense due to the minimal change in cost for this option and the low amount of change required, however it is important to note that this strategy does consists of a longer system time. Surprisingly, the Swap and Reduce strategies scored the same. The Same strategy was the highest total at 2.9, mostly due to the significant upsurge in pricing for the district.

The scoring matrix was investigated further to understand how modifying the weights could change the best result given from the matrix. First the weights were changed to favor time over cost, and to give the 2.5% categories from Table 16 more importance in the decision. The amount of change, or learning curve, was also minimized in this weight category because ultimate this would no longer be an obstacle after implementation. The new specific weights and results can be seen in Table 17.

Table 17: Alternative Scoring Matrix 1 – Time Over Costs and Minimal Learning Curve Impact

	SWAP	PUSH	REDUCE	SAME
Costs (30%)	2	1	2	4
Time (40%)	3	3	2	1
Amount of Change Required (5%)	2	1	4	2
Effect on Morning/ After Care (8%)	1	2	1	1
Athletics (7%)	2	1	1	1
Assumption School (8%)	1	2	2	1
Miscellaneous (2%)	1	1	1	1
SCORE	2.22	1.96	1.93	1.95

Interestingly, with this alternate matrix the range of results was much closer than the original matrix. Due to the decreased emphasis on amount of change, and the priority of time over cost, Reduce was selected as the most optimal solution. This was closely followed with the Same and Push Options. A reminder that Same's biggest weakness is the cost, and Push's biggest weakness is the length of its schedule in comparison to other options.

The last scoring matrix that was created took the top three categories of importance identified in the original matrix and made these each a constant weight of 30%. I left the other 4 categories unaltered at 2.5% The results from the matrix can be seen in Table 18.

Table 18: Alternative Scoring Matrix 2 – Costs, Time and Amount of Change at 30%, others at 2.5%

	SWAP	PUSH	REDUCE	SAME
Costs (30%)	2	1	2	4
Time (30%)	3	3	2	1
Amount of Change Required (30%)	2	1	4	2
Effect on Morning/ After Care (2.5%)	1	2	1	1
Athletics (2.5%)	2	1	1	1
Assumption School (2.5%)	1	2	2	1
Miscellaneous (2.5%)	1	1	1	1
SCORE	2.23	1.65	2.525	2.2

As seen in the score row of Table 18, by making the top three categories all 30%, the Push Option dominates the scoring and Reduce loses quite significantly.

By creating three different scoring matrices, each with varying weights, I got three different optimal options. Therefore, the power of the scoring matrix really depends on how the user selects the weights. If the school committee makes a final decision on the optimal solution by using the scoring matrix, it is crucial to discuss the group's top priorities. Community members could even be asked to rank these categories in a questionnaire.

5. Conclusions, Recommendations, and Reflection

This section discusses the conclusions and recommendations drawn from the completed background research, and the analyses of *swapping* start times among schools, *pushing* all start times later, *reducing* the number of iterations a bus takes, and purchasing additional buses to allow the high school to start at the *same* time as another school. A personal reflection, required by Worcester Polytechnic Institute, details what I learned and completed during the project experience.

Summary of Strategies

To summarize the analysis of each strategy, I utilized a red, yellow, and green system. This system, similar to a stop light indicates the strategies that I would advise against, those that I would use (but not optimally), and those that I believe would work the best.

Red - I put the Same option in the red category. Although it does provide ultimate flexibility in the start and end of the high school day, I believe there are not enough positives to justify increasing the daily transportation budget by 80.6%.

Yellow – I put the Swap option in the yellow category. Although there are no changes to the budget, and the Elmwood students would make it home at the same time, the Shaw students/families may feel disadvantaged for the sake of the high school students. Even though it would work, and it is feasible, in my opinion the Swap strategy is just a more complex version of push.

Green – I labelled both the Push and Reduce options green, as these strategies seem best suited for the system. The Push option (minus the 50-minute push), allows the community to ease into the transition by keeping costs, systems, and routes the same. The Reduce option, although it has the biggest learning curve, is the strategy that reduces overall system time. Therefore, it allows the district to condense the amount of time needed between schools. It does however, require an approximately 2% increase in budget.

Recommendations

I recommend that the Millbury Public School District implement a combination of the Push and Reduce Strategies. By pushing the high school back 25-30 minutes, and utilizing the Reduce strategy, the junior high and high school students can get extra sleep time that is currently being wasted in the system by utilizing a three-tier versus a two-tier route. This allows Elmwood to stay almost exactly the same, and Shaw's time to be pushed back accordingly. This solution would allow for additional morning time for the students in grades 7-12, but not significantly affect all other parties.

The next step to implement any of these strategies would be to work with the bus company to indicate the final feasibility and costs of the selected options. This would give the Millbury School District officials information that can be used to make the final decision. I would also recommend that the district begin getting feedback from the

community after the national pandemic is overcome to brace them for this potential change.

Outside of the realm of this project's particular scope, I would recommend that the high school reduce their current routes (10 full, 1 mini bus) to a maximum of 10 buses. Given ridership and capacity numbers it can certainly be accomplished. This would save the district financial resources. In addition, during the school committee meeting one member mentioned the idea of having students register with intention to take the bus, although not implement a charge. I personally think that this is a great idea. If the district could learn which specific students are never intending to take the buses this would 1) Reduce predicted (and actual) times of the route 2) Allow for an additional study on capacity to be done and possibly eliminate more buses (especially on the MJSHS side).

Reflection

(Required by Worcester Polytechnic Institute for all Industrial Engineering Students)

Discussion of Design in the Context of the Project

This project involved integrating multiple engineering design methods. Optimization, financial methods, process planning and control/analysis and improvement, along with transportation layout, and human factors all informed the study. By looking at the current bus transportation and the Millbury Public Schools current budget, I was tasked with designing optimal processes that involved budget changes, the layout of the town, the residential location of students and the locations of the school. I also needed to utilize time studies to ensure that a bus can get students picked up and to school by the pre-determined time. This integrated the students, the buses, and the school systems. The fundamental elements utilized in the design process were identifying opportunities to investigate, generating multiple options, performing an analysis on these scenarios, and considering the risks and trade-offs of each option. Each option had its own analysis to complete, and at the conclusion of the project it was required for me to compare them to one another.

Discussion of Constraints Considered in the Design and Broader Impact

There were multiple constraints considered in this project. There was the financial budget of the Millbury Public School System, the roadways and layout of the town, the number of students in the town (where they lived and their grade levels), the capacity of the buses, the total time that students are required to be in school, the political side of combining younger students with older students, the limitation of students getting home at a reasonable time, athletics, the need to transport Assumption students, and more. These were all addressed in their own ways in the strategies in which they were applicable. They influenced the recommended actions simply because I could not give certain options as a possibility if they did not fit into these basic constraints. On a broader scale this project serves as a piece of the puzzle for the societal initiative of pushing back start times of schools for adolescents and how to make transportation possible for doing this.

Discussion of Experience Acquiring and Applying New Knowledge

I think the key item that I learned not covered in coursework was that there is not always set information available and I either need to discover a way to get it or I need to find resources to make an educated guess. I did all of the learning about this project through meetings with the Millbury Public School System's Administration and researching online. I was able to find the needed information through news articles and in files found on different school districts' websites.

Discussion of Teamwork in Project

My experience with teamwork was nontraditional from the typical MQP experience. Since I did the project individually, the team did not consist of other students, but professionals in their fields. I communicated weekly in person with Mr. Gregory Myers, Superintendent of the Millbury Public Schools, and frequently with Mr. Richard Bedard, the School's Business Manager. These meetings lead to brainstorming, and discussions of concerns and clarification, amongst other things. I believe this experience prepped me more for my future career. In industry, I will be collaborating with people of various expertise and knowledge, who have different jobs than me. Therefore, although I will have team members to discuss information and ideas with, it will ultimately be individual work. This project allowed me to become more accustomed to this way of working, while having my project advisor helping to ensure that I stayed on track.

7. Works Cited

AA Transportation. (2020). *School Bus Services*. Retrieved May 4, 2020, from AA Transportation: https://aatransportation.com/school-bus-services

AA Transportation and MPS. (2019). *Millbury Bus Routes 2019-2020 8-14-19 UnPublished.* Excel, Millbury.

Assumption School. (2016). *Assumption School Guidebook 2016-2017.* Retrieved 2020, from Assumption Catholic School: https://d2y1pz2y630308.cloudfront.net/20782/documents/2018/7/guidebook.pdf

Auburn Public Schools. (2019, August 26). *Transportation*. Retrieved 2020, from Auburn Public Schools: https://www.auburn.k12.ma.us/district/transportation

Auburn Public Schools. (n.d.). *Auburn Public Schools Index*. Retrieved 2020, from Auburn Public Schools: https://www.auburn.k12.ma.us/schools

Bedard, R. (2019, December 10). *School Bus Invitation to Bid Results 12-10-19.* Retrieved 2020, from Millbury Public Schools.

Blackstone Valley Regional Vocational Technical High School. (2019). *New School Year, New Buses.* Retrieved 2020, from Blackstone Valley Tech: https://www.valleytech.k12.ma.us/Page/1025

Bowles, S. Q. (2018). *Committe Weigh Family Impact on Proposed School Start Times.* Retrieved 2020, from Grafton News: https://www.thegraftonnews.com/articles/committee-weigh-family-impact-on-proposed-school-start-times/

Boynton, D. (2015, January 10). *Northbridge Busing Cutbacks Reduced.* Retrieved 2020, from Telegram & Gazette: https://www.telegram.com/article/20150110/NEWS/301109827

Breus, M. (2018, July 10). *New Science On Teen Sleep You NEED To Know.* Retrieved 2020, from The Sleep Doctor - Michael J. Breus, PhD: https://thesleepdoctor.com/2018/07/10/new-science-on-teen-sleep-you-need-to-know/

Chen, D.-S., Kallsen, H. A., & Snider, R. C. (1988). School bus routing and scheduling: An expert system approach. *Computers and Industrial Engineering, 15*(1-4), 179-183.

Cress, J., & Bupp, M. (2016, September 4). *Experts explain the process behind school bus routes.* Retrieved 2020, from The Sentinel: https://cumberlink.com/news/local/closer_look/experts-explain-the-process-behind-school-bus-routes/article_abd8119a-1ad4-50f1-9969-479ecb1a3278.html

(2014, December 01). December 1, 2014 Greater Boston Special. (W. Boston, Interviewer) PBS. WGBH, Boston.

Dreilinger, D. (2019, Summer). How To Make School Start Later. *Education Next, 19*(3), 46-52.

Ellement, F. R. (2009, March 29). *For sleepy students, more time to recharge, But plan to shift school start times in Duxbury catches some off guard.* Retrieved 2020, from Boston.com: http://archive.boston.com/news/local/articles/2009/03/29/for_sleepy_students_more_time_to_recharge/?page=1

Elmwood Street School. (2019). *Elmwood Handbook 2019-2020.* Retrieved 2020, from Elmwood Street Elementary School: https://drive.google.com/file/d/1xOk4ahOxZKimj1PbCbDQQ0ZenD20L88c/view

Enrollment Projection Team. (2017). *Preliminary Enrollment Questionnaire and Baseline Project.* Massachusetts School Building Authority. Boston: Massachusetts School Building Authority (MSBA).

Ernenwein, R., & Bedard, R. (2019, December 10). *Millbury Public Schools Invitation for Bids - Results and Minutes.* Retrieved 2020, from Millbury Schools: https://www.millburyschools.org/cms/lib/MA02212733/Centricity/Domain/14/School%20Bus%20Bid%20Invitation%20to%20Bid%20Bid%20Results%2012-10-19.pdf

Fraser, D. (2010, January 10). *Later start time lauded at Nauset High.* Retrieved 2020, from Cape Cod Times: https://www.capecodtimes.com/article/20120110/NEWS/201100313

Gills, H. (2017, July 11). *BVT Negotiates New Bus Contract.* Retrieved 2020, from The Milford Daily News: https://www.milforddailynews.com/news/20170711/bvt-negotiates-new-bus-contract

Godfrey, T. (2017, April 27). *Westborough school committee approves school start time changes.* Retrieved 2020, from Westborough Wicked Local: https://westborough.wickedlocal.com/news/20170427/westborough-school-committee-approves-school-start-time-changes

Grafton Later Start Time Committee. (2019). *Articles and Pollicies Regarding Later Start Times.* Retrieved 2020, from Later Start Times - Grafton Public Schools: https://www.graftonps.org/Page/4138

Grafton Later Start Time Committee. (2019). *Later Start Times Committee Research Summary.* Retrieved 2020, from Later Start Times - Grafton Public Schools: https://www.graftonps.org/Page/4256

Grafton Public Schools. (2018, April 23). *Overview of a Three Tier Transportation System 4/23/18.* Retrieved 2020, from Later Start Times - Grafton Public Schools: https://www.graftonps.org/Page/4144

Grafton Public Schools. (2018). *School Start Time Committe Planning.* Retrieved 2020, from Later Start Times and Grafton Public Schools: https://www.graftonps.org/Page/4137

Grafton Public Schools. (2019). *Later Start Times FAQs.* Retrieved 2020, from Later Start Times - Grafton Public Schools: https://www.graftonps.org/Page/4265

Grafton's Later Start Time Committee. (2019, April 30). *Later Start Times Committee Recommendation to School Committee 4/30.* Retrieved 2020, from Later Start Times - Grafton Public Schools: https://www.graftonps.org/laterstarttimes

Jacob, B. A., & Rockoff, J. E. (2011). Organizing Schools to Improve Student Achievement: Start Times, Grade Configurations, and Teacher Assignments. *The Hamilton Project.* The Hamilton Projecy.

Kelly, Q. (2019, September 5). *Cohasset to adjust school start times, move Middle/High School later in 2020.* Retrieved 2020, from Wicked Local Concord: https://concord.wickedlocal.com/news/20190905/cohasset-to-adjust-school-start-times-move-middlehigh-school-later-in-2020

Lean Six Sigma Definition. (n.d.). *Six Sigma.* Retrieved 2020, from Lean Six Sigma Definition: http://www.leansixsigmadefinition.com/glossary/six-sigma/

Liesener, T. (2013, November 09). *PDCA, A3, DMAIC, 8D/PSP - what are the differences?* Retrieved 2020, from Kaizen Factory: https://kaizen-factory.com/2013/09/11/pdca-a3-dmaic-8dpsp-what-are-the-differences/

MapQuest. (2020). *Route Planner: Optimize routes, save time*. Retrieved April 16, 2020, from Route Planner by MapQuest: https://www.mapquest.com/routeplanner

Mckinstry, A. (2019, February 26). *FY2020 Budget School Department -Superintendent's Recommended Budget.* Retrieved 2020, from Northbridge Public Schools:

https://www.nps.org/sites/northbridgeps/files/uploads/superintendents_proposed_budget_presenation_2-26-19_0.pdf
METCO. (2020). *What is METCO?* Retrieved 2020, from METCO - The Metropolitan Council for Educational Oppertunity: https://metcoinc.org/services/apply/
Midge, C., & Committee, S. T. (2017, September). *Proposed Change to School Start Times - Letter.* Retrieved 2020, from Weston Massachusetts Public Schools: https://www.westonschools.org/blog/2017/10/23/proposed-change-school-start-times/
Millbury Public Schools. (2020). *Millbury Central Office*. (Blackboard) Retrieved 2020, from Millbury Public Schools: https://www.millburyschools.org
Northbridge Public Schools Transportation. (n.d.). *Transportation Services*. Retrieved 2020, from Transportaion Policy & Information: https://www.nps.org/sites/northbridgeps/files/pages/school_committee_transportation_policy_-_eeaa.pdf
O'Donnell, B. (2019). *2019-2020 Bus Route*. (CivicPlus) Retrieved 2020, from Northbridge Public Schools: https://www.nps.org/district/transportation/pages/bus-routes
School Start Time Committee (Westborough). (2017). *Transportation Study Questions.docx.* Retrieved 2020, from Westborough Public Schools: https://drive.google.com/file/d/0BwiJiCcA2r-haEQtOXVtM1lKdEk/view
School Start Time Subcomittee Westborough Public Schools. (2017). *School Start Time Report - Final Report and Recommendations.* Westborough Public Schools.
Start School Later. (2020). *Massachusetts FAQs.* Retrieved 2020, from Start School Later: https://www.startschoollater.net/massachusetts-faqs.html#answer11
Start School Later. (2020). Massachusetts School Start Times. *Excel File*. Start School Later. Net.
Start School Later. (2020). *Success Stories.* Retrieved 2020, from Start School Later: https://www.startschoollater.net/success-stories.html
Start Time/Scheduling Innovation Steering Committee. (2018). *Resources to Learn More About Adolescent Sleep and School Start Times.* Retrieved 2020, from Weston Massachusetts Public Schools: https://www.westonschools.org/school-committee/start-timescheduling-innovation-steering-committee/resources-learn-adolescent-sleep-school-start-times/
Tantasqua and Union 61. (2019, August). *2019-2020 Bus Routes*. Retrieved 2020, from Tantasqua and Union 61: http://www.tantasqua.org/TRSD/busroutes/index.htm
Tantasqua and Union 61. (2020). *Home Page*. Retrieved 2020, from Tantasqua and Union 61: http://www.tantasqua.org
Transfort's Technical Advisory Committee & Project Management Team. (2015). *Transfort: Bus Stop Design Standards and Guidlines.* Fort Collin, CO: RideTransfort.
Weston Public Schools. (2018). *New School Schedule for 2018-2019*. Retrieved 2020, from Weston Massachusetts Public Schools: https://www.westonschools.org/school-committee/start-timescheduling-innovation-steering-committee/proposed-schedule-2018-2019/
Wirzbicki, C. (2020). *Auburn Public Schools Bus Transportation Invitation to Bid Package, Addendums, and Bid Results*. Retrieved 2020, from Auburn Public Schools: https://www.auburn.k12.ma.us/departments/business/auburn-public-schools-bus-transportation-invitation-to-bid-package
Wyner, M. (2019, December 22). *Weston reports positive feedback to later school start times.* Retrieved 2020, from The Milford Daily News: https://www.milforddailynews.com/news/20191222/weston-reports-positive-feedback-to-later-school-start-times

8. Appendix

8.1 The Route Time Comparison Calculations

Buses	Difference in Routes (Shaw - High School)	Higher Time	Difference in Routes (Shaw - Elmwood)	Higher Time	Difference in Routes (High School - Elmwood)	Higher Time
1	7	SHAW	7	SHAW	0	SAME
2	5	SHAW	5	SHAW	0	SAME
3	-2	High School	3	SHAW	5	High SCHOOL
4	5	SHAW	0	SAME	-5	ELMWOOD
5	6	SHAW	2	SHAW	-4	ELMWOOD
6	5	SHAW	-6	ELMWOOD	-11	ELMWOOD
7	-5	High School	-7	ELMWOOD	-2	ELMWOOD
8	-1	High School	-5	ELMWOOD	-4	ELMWOOD
9	16	SHAW	4	SHAW	-12	ELMWOOD
10	3	High School	3	SHAW	0	SAME
MB	1	SHAW	8	SHAW	7	High SCHOOL

8.2 Swap Excel File the Earliest Arrival at Millbury High School

Bus 1

BUS 1		
AM	MILLBURY HIGH SCHOOL	PM
7:30 AM	WHEELOCK AVE @ 1 LT HAYNES DR	2:54 PM
7:31 AM	14 LT HAYNES DR	2:55 PM
7:34 AM	GRAFTON RD @ SCOTT ST	2:59 PM
7:34 AM	GRAFTON RD @ MIDDLETON ST	2:59 PM
7:35 AM	GRAFTON RD @ RAYMOND ST	3:00 PM
7:36 AM	GRAFTON RD @ OAKES ST	3:01 PM
7:38 AM	GRAFTON RD @ CEDAR AVE	3:03 PM
7:39 AM	GRAFTON RD @ HASTINGS AVE	3:04 PM
7:41 AM	284 RIVERLINE ST	3:06 PM
7:42 AM	261 RIVERLINE ST	3:07 PM
7:44 AM	257 RIVERLINE ST	3:08 PM
7:44 AM	RIVERLINE ST @ RIVERLINE PKWY	3:08 PM
7:45 AM	RAILROAD AVE @ GOVER RD	3:09 PM
7:47 AM	RIVERLINE ST & BRIGHTSIDE DR	3:11 PM
7:48 AM	RIVERLINE ST & MAYFAIR DR	3:12 PM
7:48 AM	RIVERLINE ST @ WILLIAMS ST	3:12 PM
8:05 AM	MILLBURY JUNIOR SENIOR HIGH SCHOOL	2:37 PM
BUS 1		
AM	RAYMOND E SHAW SCHOOL	PM
6:40 AM	WHEELOCK AVE @ 1 LT HAYNES DR	2:05 PM
6:41 AM	14 LT HAYNES DR	2:06 PM
6:45 AM	GRAFTON RD @ MIDDLETON ST	2:09 PM
6:45 AM	GRAFTON RD @ RAYMOND ST	2:10 PM
6:46 AM	1516 GRAFTON RD	2:12 PM
6:46 AM	GRAFTON RD @ CEDAR AVE	2:12 PM
6:47 AM	GRAFTON RD @ HASTINGS AVE	2:13 PM
6:49 AM	284 RIVERLINE ST	2:15 PM
6:50 AM	257 RIVERLINE ST	2:16 PM
6:52 AM	RIVERLINE ST @ COLTON RD	2:18 PM
6:53 AM	149 RIVERLINE ST	2:18 PM
6:53 AM	RIVERLINE ST @ RIVERLINE PKWY	2:19 PM
6:54 AM	RIALROAD AVE @ GOVER RD	2:20 PM
6:55 AM	25 GOVER RD	2:22 PM
6:58 AM	127 RIVERLINE ST	2:25 PM
6:59 AM	119 RIVERLINE ST	2:26 PM
6:59 AM	RIVERLINE ST @ BRIGHTSIDE ST	2:26 PM
7:00 AM	RIVERLIN @ BLANCHARD DR	2:27 PM
7:01 AM	64 RIVERLINE ST	2:28 PM
7:02 AM	RIVERLINE ST @ MAYFAIR DR	2:29 PM
7:03 AM	65 CANAL ST (Cordis Mills Apt)	2:30 PM
7:12 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Bus 2

BUS 2		
AM	**MILLBURY HIGH SCHOOL**	**PM**
6:41 AM	WHEELOCK AVE @ MARGARET ST	2:07 PM
6:42 AM	MACARTHUR DR @ TIFFANY CIR	2:08 PM
6:43 AM	MACARTHUR DR @ ROLLIE SHEPARD DR	2:09 PM
6:47 AM	WHEELOCK AVE @ ROE LN/JOHN ST	2:13 PM
6:47 AM	WHEELOCK AVE @ MARION AVE	2:13 PM
6:49 AM	WHEELOCK AVE @ EAST MILLBURY PARK	2:15 PM
6:55 AM	GRAFTON RD @ ABBOTT PL	2:20 PM
6:56 AM	GRAFTON RD @ ELLENWOOD RD	2:21 PM
6:57 AM	GRAFTON RD @ ACKERMAN RD	2:22 PM
6:58 AM	1465 GRAFTON RD	2:23 PM
7:00 AM	WARD ST @ KATHERINE ST	2:25 PM
7:10 AM	MILLBURY JUNIOR SENIOR HIGH SCHOOL	2:37 PM

BUS 2		
AM	**RAYMOND E SHAW SCHOOL**	**PM**
7:20 AM	WHEELOCK AVE @ MARGARET ST	2:07 PM
7:21 AM	MACARTHUR DR @ TIFFANY CIR	2:08 PM
7:23 AM	85 MACARTHUR DR	2:09 PM
7:24 AM	MONTGOMERY DR @ ROLLIE SHEPARD DR	2:10 PM
7:24 PM	MONTGOMERY DR @ MACARTHUR DR	2:10 PM
7:27 AM	86 WHEELOCK AVE	2:14 PM
7:28 AM	WHEELOCK AVE @ JOHN ST	2:14 PM
7:29 AM	WHEELOCK AVE @ MARION AVE	2:15 PM
7:30 AM	184 WHEELOCK AVE	2:16 PM
7:35 AM	GRAFTON RD @ ABBOTT PL	2:21 PM
7:36 AM	GRAFTON RD @ ELLENWOOD ED	2:22 PM
7:37 AM	1527 GRAFTON RD	2:23 PM
7:40 AM	15 SHIRLEY AVE	2:26 PM
7:43 AM	193 WHEELOCK AVE	2:29 PM
7:44 AM	187 WHEELOCK AVE	2:30 PM
7:54 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Bus 3

BUS 3			
AM		**MILLBURY HIGH SCHOOL**	**PM**
AM	6:45 AM	211 MILLBURY AVE	2:06
	6:46 AM	301 MILLBURY AVE	2:07
	6:47 AM	401 MILLBURY AVE	2:08
	6:47 AM	401 MILLBURY AVE	2:08
	6:48 AM	MILLBURY AVE @ LAKE ST	2:09
	6:48 AM	MILLBURY AVE @ OAK ST	2:09
	6:49 AM	714 MILLBURY AVE	2:10
	6:50 AM	MILLBURY AVE @ HAYWARD LN	2:11
	6:50 AM	MILLBURY AVE@ WILSON RD	2:11
	6:51 AM	MILLBURY AVE @ MANOR RD	2:12
	6:52 AM	MILLBURY AVE @ SHORE TERR	2:13
	6:53 AM	902 MILLBURY AVE	2:14
	6:54 AM	972 MILLBURY AVE	2:15
	6:58 AM	972 MILLBURY AVE	2:17
	6:54 AM	902 MILLBURY AVE	2:15
	5:55 AM	OAK POND AVE @ BROADMEADOW AVE	2:16
	6:56 AM	OAK POND AVE @ SKYVIEW DR	2:17
	6:57 AM	61 OAK POND AVE	2:18
	6:57 AM	OAK POND AVE @ OVERLOOK AVE	2:18
	6:59 AM	WHEELOCK AVE @ RINDGE ST	2:19
	6:59 AM	WHEELOCK AVE @ EPPING ST	2:19
	7:00 AM	14 WHEELOCK AVE	2:20
	7:10 AM	MILLBURY JUNIOR SENIOR HIGH SCHOOL	2:25

BUS 3			
AM		**RAYMOND E SHAW SCHOOL**	**PM**
	7:25 AM	6 MILLBURY AVE	2:08
	7:25 AM	714 MILLBURY AVE	2:37 PM
	7:26 AM	301 MILLBURY AVE	2:38 PM
	7:26 AM	401 MILLBURY AVE	2:38 PM
	7:28 AM	MILLBURY AVE @ LAKE ST	2:40 PM
	7:28 AM	MILLBURY AVE @ OAK ST	2:40 PM
	7:29 AM	714 MILLBURY AVE	2:41 PM
AM	7:30 AM	MILLBURY AVE @ HAYWARD LN	2:42 PM
AM	7:30 AM	MILLBURY AVE @ MANOR RD	2:42 PM
	7:31 AM	708 MILLBURY AVE	2:43 PM
	7:31 AM	MILLBURY AVE @ DOROTHY LANDING	2:43 PM
	7:32 AM	714 MILLBURY AVE	2:44 PM
	7:33 AM	OAK POND AVE @ BROADMEADOW AVE	2:45 PM
	7:33 AM	OAK POND AVE @ SKYVIEW DR	2:45 PM
	7:34 AM	61 OAKPOND	2:46 PM
	7:34 AM	OAKPOND AVE @ OVERLOOK AVE	2:46 PM
	7:36 AM	WHEELOCK AVE @ CRISTO LN	2:48 PM
	7:36 AM	WHEELOCK AVE & RINDGE ST	2:48 PM
	7:37 AM	WHEELOCK AVE @ EPPING ST	2:20
	7:48 AM	RAYMOND E SHAW SCHOOL	1:55

Bus 4

BUS 4		
AM	**MILLBURY HIGH SCHOOL**	**PM**
AM	6:59 AM PARK HILL AVE	2:04
	7:00 AM PARK HILL AVE @ HOLMAN RD	2:05
	7:01 AM PARK HILL AVE @ AZALEA CIR	2:06
	7:01 AM PARK HILL AVE @ HOLLYWOOD AVE	2:06
	7:02 AM PARK HILL AVE @ JOHNSON ST	2:07
	7:04 AM MILLBURY AVE @ MILLBURY TERR	2:09
	7:05 AM MILLBURY AVE @ GLEN AVE	2:10
	7:07 AM MILLBURY AVE @ CROYDEN ST	2:12
	7:08 AM MILLBUR AVE @ WOODROW RD	2:13
	7:08 AM MILLBURY AVE @ DOROTHY RD	2:13
	7:10 AM MILLBURY AVE @ WILSON RD	2:15
	7:11 AM HAYWARD GLEN DR @ WINGFOOT LN/ KEITH DAVID DR	2:16
	7:12 AM MAPLE LN @ HOWE LN	2:17
	7:12 AM MILLBURY AVE	2:17
	7:15 AM MILLBURY JUNIOR SENIOR HIGH SCHOOL	2:27

BUS 4		
AM	**RAYMOND E SHAW SCHOOL**	**PM**
	7:31 AM MARTIN ST @ DEWEY AVE	2:10
	7:31 AM MARTIN ST	2:35 PM
	7:32 AM MARTIN ST	2:36 PM
	7:32 AM MARTIN ST	2:36 PM
	7:33 AM PARK HILL AVE	2:37 PM
	7:34 AM PARK HILL AVE @ WELDON DR	2:38 PM
	7:35 AM PARK HILL AVE @ PRIMROSE LN	2:39 PM
	7:35 AM PARK HILL AVE @ HOLLYWOOD	2:39 PM
AM	7:36 AM PARK HILL AVE @ HEATHER ST	2:40 PM
	7:39 AM 28 MILLBURY AVE	2:43 PM
	7:39 AM MILLBURY AVE @ GLEN AVE	2:43 PM
	7:39 AM MILLBURY AVE @ CROYDEN ST	2:43 PM
	7:40 AM MILLBURY AVE @ WOODROW RD	2:44 PM
	7:41 AM MILLBURY AVE @ DOROTHY RD	2:45 PM
	7:42 AM 65 MILLBURY AVE	2:46 PM
	7:42 AM MILLBURY AVE @ WILSON RD	2:46 PM
	7:43 AM HAYWARD GLEN DR @ AUGUSTA DR	2:47 PM
	7:45 AM MAPLE LN @ JACKSON LN	2:49 PM
	7:45 AM MILLBURY AVE @ LINDA AVE	2:49 PM
	7:46 AM HOWE AVE	2:25
	7:52 AM RAYMOND E SHAW SCHOOL	1:55

Bus 5

AM		MILLBURY HIGH SCHOOL	PM
AM	6:57 AM	CAROUSEL DR @ CHERYL LN	2:08
	6:58 AM	RAYBURN DR	2:09
	6:59 AM	RAYBURN DR	2:10
	7:00 AM	AYBURN DR @ DANIELLE	2:11
	7:01 AM	DANIELLE DR	2:12
	7:02 AM	ANIELLE DR @ BRANEY RD	2:13
	7:03 AM	RANEY RD @ COLDBROOK RD	2:14
	7:03 AM	OODRIDGE RD @ COLDBROOK RD	2:14
	7:05 AM	RAFTON ST @ AUTUMN GATE CIR	2:15
	7:06 AM	RAFTON ST @ BUNKER HILL RD	2:16
	7:08 AM	5 GRAFTON ST	2:18
	7:09 AM	5 GRAFTON ST	2:33
	7:15 AM	LLBURY JUNIOR SENIOR HIGH SCHOOL	2:33
BUS 5			
AM		**RAYMOND E SHAW SCHOOL**	**PM**
	7:34 AM	CAROUSEL DR	2:13
	7:35 AM	AROUSEL DR @ CHERYL LN	2:39 PM
AM	7:36 AM	CAROUSEL DR @ RAYBURN DR	2:40 PM
	7:37 AM	AYBURN DR @ HORSESHOE LN (2nd entrance)	2:41 PM
	7:38 AM	AYBURN DR @ DANIELLE DR	2:42 PM
	7:38 AM	DANIELLE DR	7:42 PM
	7:39 AM	RONIN BROOK WY @ DIANA HILL RD	2:43 PM
	7:40 AM	RANEY RD @ COLDBROOK RD	2:44 PM
	7:41 AM	OLDBROOK RD @ WOODRIDGE LN	2:45 PM
	7:42 AM	RAFTON ST @ AUTUMN GATE CIR	2:46 PM
	7:43 AM	4 GRAFTON ST	2:47 PM
	7:43 PM	8 GRAFTON ST	2:47 PM
	7:46 AM	UNKER HILL RD @ THE SHED	3:00 PM
	7:49 AM	OMIN DR @ JONATHAN AVE	3:03 PM
	7:50 AM	GRAFTON ST	3:04 PM
	7:51 AM	RAFTON ST @ MEMORIAL DR	3:05 PM
	7:51 AM	RAFTON ST @ BELVILLE LN	2:30
	7:58 AM	AYMOND E SHAW SCHOOL	1:55

Bus 6

BUS 6		
AM	**MILLBURY HIGH SCHOOL**	**PM**
6:56 AM	20 PROVIDENCE RD	2:04 PM
6:57 AM	MAPLE ST @ CORAL ST	2:05 PM
6:58 AM	MAPLE ST @ CURVE ST	2:06 PM
7:00 AM	SO MAIN @ SYCAMORE ST	2:07 PM
7:00 AM	SO MAIN ST @ WOODLAND DR	2:07 PM
7:01 AM	SO MAIN ST @ RICE RD	2:08 PM
7:02 AM	120 SO MAIN ST	2:09 PM
7:04 AM	WOODLAND ST @ FOREST ST	2:11 PM
7:05 AM	WOODLAND ST @ HERRICKS LN	2:12 PM
7:06 AM	HERRICKS LN @ JESSICA DR	2:13 PM
7:07 AM	WOODLAND DR @ LESLIE LN	2:14 PM
7:08 AM	LESLIE LN @ SULLIVAN PL	2:15 PM
7:09 AM	SULLIVAN PL @ SYCAMORE ST	2:16 PM
7:15 AM	MILLBURY JUNIOR SENIOR HIGH S	2:28 PM
BUS 6		
AM	**RAYMOND E SHAW SCHOOL**	**PM**
7:31 AM	ELM ST @ ELM CT	2:08 PM
7:32 AM	109 ELM ST	2:34 PM
7:34 AM	34 ELM ST	2:36 PM
7:35 AM	PROVIDENCE ST @ PEARL ST	2:37 PM
7:36 AM	48 MAPLE ST	2:38 PM
7:36 AM	MAPLE ST @ CURVE ST	2:38 PM
7:37 AM	34 SO MAIN ST	2:39 PM
7:37 AM	S MAIN ST @ FONTAINE ST	2:39 PM
7:38 AM	CURVE ST @ JACKIE DR	2:40 PM
7:40 AM	S MAIN ST @ WOODLAND ST	2:42 PM
7:41 AM	69 S MAIN ST	2:43 PM
7:42 AM	ALDRICH AVE @ THOMAS HILL RD	2:44 PM
7:44 AM	86 SO MAIN ST	2:45 PM
7:45 AM	SO MAIN ST @ PHILLIPS DR	2:46 PM
7:46 AM	25 HERRICKS LN	2:47 PM
7:47 AM	HERRICKS LN @ JESSICA DR	2:48 PM
7:47 AM	JESSICA DR @ MOORE DR	2:48 PM
7:48 AM	WOODLAND ST @ LESLIE LN	2:49 PM
7:49 AM	SYCAMORE & SULLIVAN PL	2:25 PM
7:55 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Bus 7

BUS 7		
AM	**MILLBURY HIGH SCHOOL**	**PM**
6:34 AM	397 GREENWOOD ST	2:07 PM
6:34 AM	407 GREENWOOD ST	2:08 PM
6:35 AM	GREENWOOD ST @ TAINTER HILL	2:09 PM
6:36 AM	448 GREENWOOD ST	2:10 PM
6:36 AM	459 GREENWOOD ST	2:10 PM
6:37 AM	GREENWOOD ST @ CYNDY LN	2:11 PM
6:37 AM	456 GREENWOOD ST	2:11 PM
6:38 AM	9 AUBURN RD	2:12 PM
6:38 AM	17 AUBURN RD	2:12 PM
6:39 AM	56 AUBURN RD	2:13 PM
6:46 AM	26 CARLTON RD	2:21 PM
6:47 AM	38 CARLETON RD	2:21 PM
6:47 AM	77 CARLETON RD	2:22 PM
6:49 AM	376 W MAIN ST	2:23 PM
6:51 AM	8 GILBERT WAY	2:25 PM
6:52 AM	393 W MAIN ST	2:26 PM
6:53 AM	387 W MAIN ST	2:27 PM
6:54 AM	357 W MAIN ST	2:28 PM
6:56 AM	CARLETON RD @ CARLSTROM LN	2:20 PM
6:57 AM	93 ELMWOOD ST	2:31 PM
6:58 AM	ELMWOOD ST @ ELMWOOD TERR	2:32 PM
7:10 AM	MILLBURY JUNIOR SENIOR HIGH S	2:31 PM
BUS 7		
AM	**RAYMOND E SHAW SCH**	**PM**
7:20 AM	399 1/2 GREENWOOD ST	2:28 PM
7:21 AM	408 GREENWOOD ST	3:02 PM
7:21 AM	GREENWOOD ST @ TAINTER HILL	3:02 PM
7:22 AM	452 GREENWOOD ST	3:01 PM
7:22 AM	GREENWOOD ST @ CYNDY LN	3:01 PM
7:23 AM	463 GREENWOOD ST	3:01 PM
7:24 AM	16 AUBURN RD	2:49 PM
7:25 AM	56 AUBURN RD	2:50 PM
7:26 AM	64 AUBURN RD	2:51 PM
7:32 AM	11 AUBURN RD	2:49 PM
7:32 AM	5 AUBURN RD	2:49 PM
7:35 AM	372 W MAIN ST	2:44 PM
7:35 AM	376 W MAIN ST	2:44 PM
7:37 AM	9 GILBERT WY	2:46 PM
7:38 AM	393 W MAIN ST	2:47 PM
7:40 AM	49 CARLETON RD	2:42 PM
7:41 AM	29 CARLETON RD	2:41 PM
7:42 AM	63 ELMWOOD ST	2:05 PM
7:51 AM	RAYMOND E SHAW SCHOOL; 58 E	1:55 PM

Bus 8

BUS 8		
AM	**MILLBURY HIGH SCHO**	**PM**
6:45 AM	24 SINGLETARY RD	2:14 PM
6:50 AM	46 DOLAN RD	2:18 PM
6:51 AM	DOLAN RD @ SUNSET DR	2:19 PM
6:51 AM	DOLAN RD @ BAYBERRY LN	2:19 PM
6:53 AM	SO OXFORD RD @ PEGGY DR	2:21 PM
6:54 AM	W MAIN ST @ GLOVER RD	2:22 PM
6:55 AM	294 W MAIN ST	2:23 PM
6:55 AM	267 W MAIN ST	2:23 PM
6:56 AM	238 W MAIN ST	2:24 PM
6:56 AM	230 W MAIN ST	2:13 PM
6:57 AM	224 W MAIN ST	2:12 PM
6:57 AM	W MAIN ST @ HARRIS AVE	2:12 AM
6:58 AM	181 W MAIN ST	2:11 PM
6:59 AM	10 SUTTON RD	2:08 PM
7:00 AM	6 HEMLOCK DR	2:09 PM
7:00 AM	HEMLOCK DR @ BRENDA DRIVE	2:09 PM
7:02 AM	SUTTON RD @ LAUREL DR	2:10 PM
7:03 AM	164 W MAIN ST	2:07 PM
7:08 AM	MILLBURY JUNIOR SENIOR HIGH	2:26 PM
BUS 8		
AM	**RAYMOND E SHAW SC**	**PM**
7:33 AM	177 W MAIN ST	2:39 PM
7:34 AM	181 W MAIN ST	2:39 PM
7:34 AM	199 W MAIN ST	2:39 PM
7:35 AM	206 W MAIN ST	2:40 PM
7:35 AM	230 W MAIN ST	2:40 PM
7:36 AM	24 SINGLETARY RD	2:41 PM
7:42 AM	43 DOLAN RD	2:44 PM
7:43 AM	15 DOLAN RD	2:45 PM
7:43 AM	SO OXFORD RD @ PEGGY DR	2:45 PM
7:45 AM	294 W MAIN ST	2:46 PM
7:45 AM	W MAIN ST @ MCGRATH RD	2:48 PM
7:46 AM	238 W MAIN ST	2:19 PM
7:48 AM	6 SUTTON RD	2:05 PM
7:49 AM	11 HEMLOCK DR	2:36 PM
7:50 AM	SUTTON RD @ LAUREL DR	2:37 PM
7:51 AM	29 SUTTON RD	2:38 PM
7:55 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Bus 9

BUS 9		
AM	**MILLBURY HIGH SCHOOL**	**PM**
6:57 AM	BEACH ST @ BENGTSON LN	2:09 PM
6:58 AM	BEACH ST @ ALPINE ST	2:10 PM
6:59 AM	BEACH ST @ HIGH ST	2:11 PM
7:00 AM	W MAIN ST @ BURBANK/HIGH ST (	2:12 PM
7:02 AM	W MAIN ST @ RHODES ST	2:14 PM
7:03 AM	W MAIN ST @ WASHINGTON ST	2:15 PM
7:04 AM	35 W MAIN ST	2:16 PM
7:05 AM	ELM ST @ ELM CT	2:07 PM
7:10 AM	MILLBURY JUNIOR SENIOR HIGH S	2:33 PM
BUS 9		
AM	**RAYMOND E SHAW SCHOOL**	**PM**
7:25 AM	WEST ST @ CHERRY ST	3:00 PM
7:25 AM	WATERS ST @ WEST ST	3:00 PM
7:26 AM	WATERS ST @ GROVE ST	2:31 PM
7:29 AM	ELMWOOD TERR @ ALPINE ST	2:07 PM
7:30 AM	ALPINE ST @ TODD LN	2:38 PM
7:32 AM	10 BENGTSON LN	2:40 PM
7:34 AM	BENGTSON LN & BEACH ST	2:42 PM
7:35 AM	26 BEACH ST	2:43 PM
7:35 AM	18 BEACH ST	2:43 PM
7:37 AM	146 W MAIN ST	2:45 PM
7:40 AM	61 BURBANK ST	2:48 PM
7:45 AM	7 BURBANK ST	2:53 PM
7:46 AM	W MAIN ST @ HIGH/BURBANK ST	2:54 PM
7:47 AM	W MAIN @ RHODES ST	2:55 PM
7:48 PM	W MAIN ST @ GOULD ST	2:56 PM
7:49 AM	W MAIN ST @ WASHINGTON ST	2:57 PM
7:50 AM	31 W MAIN ST	2:58 PM
7:54 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Bus 10

BUS 10		
AM	**MILLBURY HIGH SCHOOL**	**PM**
6:42 AM	16 GRAFTON ST	2:10 PM
6:43 AM	84 GRAFTON ST	2:11 PM
6:45 AM	JONATHAN AVE @ MOMIN DR	2:12 PM
6:46 AM	85 GRAFTON ST	2:13 PM
6:47 AM	GRAFTON ST @ MEMORIAL DR	2:14 PM
6:49 AM	GRATON ST @ BELLVILLE LN	2:16 PM
6:57 AM	HAWTHORNE ST @ BORDER AVE	2:24 PM
6:58 AM	GREENWOOD ST @ ROGERS ST	2:25 PM
6:58 AM	GREENWOOD ST @ CHUNIS AVE	2:25 PM
6:59 AM	366 GREENWOOD ST	2:26 PM
8:59 PM	392 GREENWOOD ST	2:26 PM
7:00 PM	52 MCCRACKEN RD	2:27 PM
7:00 AM	58 MCCRACKEN RD	2:27 PM
7:01 AM	82 MCCRACKEN RD	2:28 PM
7:01 AM	92 MCCRACKEN RD	2:28 PM
7:02 AM	2 HIDDEN MEADOW DR	2:29 PM
7:04 AM	59 MCCRACKEN RD	2:31 PM
7:06 AM	27 MCCRACKEN RD	2:21 PM
7:10 AM	MILLBURY JUNIOR SENIOR HIGH S	2:30 PM

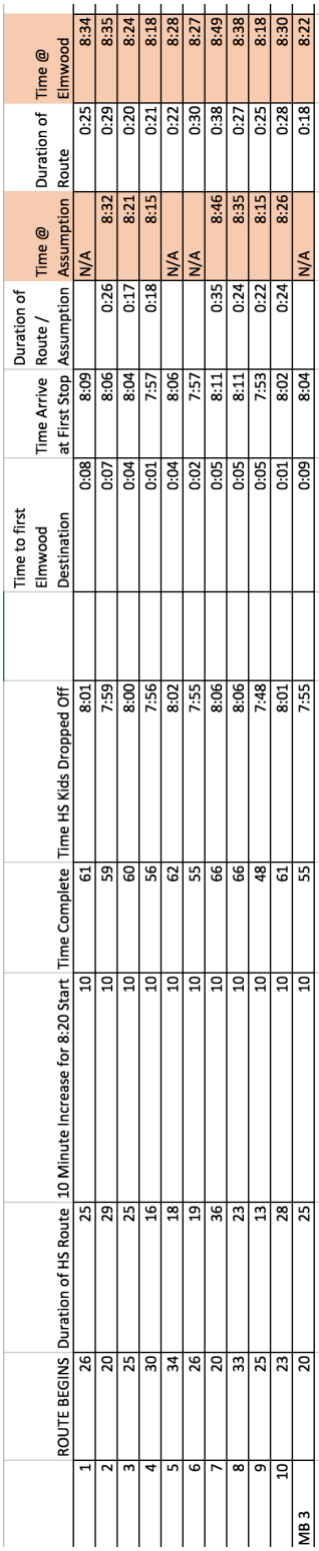
BUS 10		
AM	**RAYMOND E SHAW SCH**	**PM**
7:23 AM	MAIN ST @ CHURCH ST(Federated	2:04 PM
7:24 AM	7 PROSPECT ST	2:40 PM
7:25 AM	25 PROSPECT ST	2:41 PM
7:25 AM	PROSPECT ST @ LINDY ST	2:41 PM
7:26 AM	88 MILES ST	2:42 PM
7:26 AM	76 MILES ST	2:42 PM
7:26 AM	70 MILES ST	2:42 PM
7:27 AM	LINCOLN ST @ PARK ST	2:43 PM
7:28 AM	HAMILTON ST @ ATWOOD ST	2:44 PM
7:29 AM	19 MILES ST	2:45 PM
7:30 AM	58 MAIN ST	2:46 PM
7:30 AM	MAIN ST @ HAMILTON ST	2:46 PM
7:31 AM	150 N MAIN ST	2:47 PM
7:32 AM	228 N MAIN ST EXT	2:47 PM
7:37 AM	ELMWOOD AVE @ BORDER AVE	2:52 PM
7:38 AM	HAWTHORNE ST @ BORDER AVE	2:53 PM
7:39 AM	360 GREENWOOD ST	2:54 PM
7:40 AM	GREENWOOD ST @ CHUNIS AVE	2:55 PM
7:43 AM	82 MCCRACKEN RD	2:57 PM
7:43 AM	92 MCCRACKEN RD	2:57 PM
7:44 AM	HIDDEN MEADOW @ MCCRACKEN	2:58 PM
7:47 AM	27 MCCRACKEN RD	3:01 PM
7:50 AM	163 N MAIN ST	2:29 PM
7:54 AM	RAYMOND E SHAW SCHOOL	1:55 PM

Mini Bus 3

MB3		
AM	**MILLBURY HIGH**	**PM**
6:40 AM	46 DAVIS RD	2:15 PM
6:41 AM	48 DAVIS RD	2:16 PM
6:41 AM	55 DAVIS RD	2:16 PM
6:45 AM	50 SO OXFORD RD	2:20 PM
6:46 AM	SO OXFORD RD @ WED	2:21 PM
6:47 AM	78 S OXFORD RD	2:22 PM
6:47 AM	98 S OXFORD RD	2:22 PM
6:48 AM	SO OXFORD RD @ FEDE	2:25 PM
6:53 AM	6 STONE RD	2:30 PM
6:54 AM	22 STONE RD	2:31 PM
6:54 AM	36 STONE RD	2:31 PM
6:57 AM	19 STOWE RD	2:33 PM
7:05 AM	MILLBURY JUNIOR SEN	2:32 PM
MB3		
AM	**RAYMOND E SHA**	**PM**
7:20 AM	48 DAVIS RD	2:06 PM
7:20 AM	58 DAVIS RD	2:43 PM
7:25 AM	84 SO OXFORD RD	2:48 PM
7:26 AM	96 SO OXFORD RD	2:49 PM
7:28 AM	213 FEDERAL HILL RD	2:51 PM
7:31 AM	SO OXFORD RD @ WED	2:54 PM
7:32 AM	59 SO OXFORD RD	2:55 PM
7:36 AM	10 STONE RD	2:59 PM
7:36 AM	16 STONE RD	2:59 PM
7:37 AM	32 STONE RD	3:00 PM
7:38 AM	36 STONE RD	3:00 PM
7:41 AM	17 STOWE RD	2:25 PM
7:46 AM	RAYMOND E SHAW SCH	1:55 PM

8.3 Elmwood Afternoon and Morning Calculations for Modified Swap Option

Morning Calculations

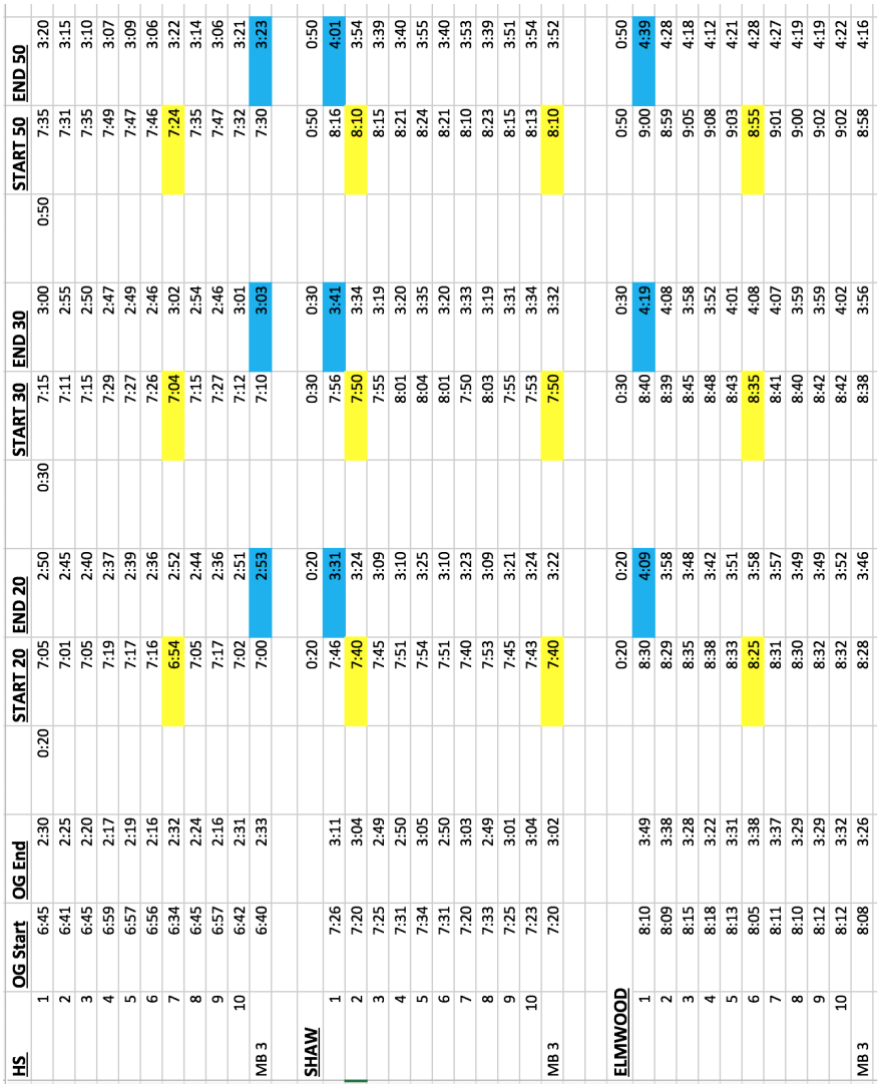


	ROUTE BEGINS	Duration of HS Route	10 Minute Increase for 8:20 Start	Time Complete	Time HS Kids Dropped Off	Time to first Elmwood Destination	Time Arrive at First Stop	Duration of Route / Assumption	Time @ Assumption	Duration of Route	Time @ Elmwood
1	26	25	10	61	8:01		0:08	8:09	N/A	0:25	8:34
2	20	29	10	59	7:59		0:07	8:06	0:26	8:32	0:29	8:35
3	25	25	10	60	8:00		0:04	8:04	0:17	8:21	0:20	8:24
4	30	16	10	56	7:56		0:01	7:57	0:18	8:15	0:21	8:18
5	34	18	10	62	8:02		0:04	8:06		N/A	0:22	8:28
6	26	19	10	55	7:55		0:02	7:57		N/A	0:30	8:27
7	20	36	10	66	8:06		0:05	8:11	0:35	8:46	0:38	8:49
8	33	23	10	66	8:06		0:05	8:11	0:24	8:35	0:27	8:38
9	25	13	10	48	7:48		0:05	7:53	0:22	8:15	0:25	8:18
10	23	28	10	61	8:01		0:01	8:02	0:24	8:26	0:28	8:30
MB 3	20	25	10	55	7:55		0:09	8:04	N/A		0:18	8:22

Afternoon Calculations

	TIME LEAVING HIGH SCHOOL		HS ROUTE		Route to Elmwood		TIME ARRIVE AT ELMWOOD AFTERNOON
1	2:38	38		26	6	70	3:10
2	2:38	38		29	11	78	3:18
3	2:38	38		25	7	70	3:10
4	2:38	38		16	6	60	3:00
5	2:38	38		18	6	62	3:02
6	2:38	38		19	3	60	3:00
7	2:38	38		36	1	75	3:15
8	2:38	38		23	5	66	3:06
9	2:38	38		13	2	53	2:53
10	2:38	38		28	5	71	3:11
MB	2:38	38		25	5	68	3:08

8.4 Push Analysis Raw Information



Overall Calculations

HS		OG Start	OG End		START 20	END 20		START 30	END 30		START 50	END 50
	1	6:45	2:30	0:20	7:05	2:50	0:30	7:15	3:00	0:50	7:35	3:20
	2	6:41	2:25		7:01	2:45		7:11	2:55		7:31	3:15
	3	6:45	2:20		7:05	2:40		7:15	2:50		7:35	3:10
	4	6:59	2:17		7:19	2:37		7:29	2:47		7:49	3:07
	5	6:57	2:19		7:17	2:39		7:27	2:49		7:47	3:09
	6	6:56	2:16		7:16	2:36		7:26	2:46		7:46	3:06
	7	6:34	2:32		6:54	2:52		7:04	3:02		7:24	3:22
	8	6:45	2:24		7:05	2:44		7:15	2:54		7:35	3:14
	9	6:57	2:16		7:17	2:36		7:27	2:46		7:47	3:06
	10	6:42	2:31		7:02	2:51		7:12	3:01		7:32	3:21
MB 3		6:40	2:33		7:00	2:53		7:10	3:03		7:30	3:23
SHAW					0:20	0:20		0:30	0:30		0:50	0:50
	1	7:26	3:11		7:46	3:31		7:56	3:41		8:16	4:01
	2	7:20	3:04		7:40	3:24		7:50	3:34		8:10	3:54
	3	7:25	2:49		7:45	3:09		7:55	3:19		8:15	3:39
	4	7:31	2:50		7:51	3:10		8:01	3:20		8:21	3:40
	5	7:34	3:05		7:54	3:25		8:04	3:35		8:24	3:55
	6	7:31	2:50		7:51	3:10		8:01	3:20		8:21	3:40
	7	7:20	3:03		7:40	3:23		7:50	3:33		8:10	3:53
	8	7:33	2:49		7:53	3:09		8:03	3:19		8:23	3:39
	9	7:25	3:01		7:45	3:21		7:55	3:31		8:15	3:51
	10	7:23	3:04		7:43	3:24		7:53	3:34		8:13	3:54
MB 3		7:20	3:02		7:40	3:22		7:50	3:32		8:10	3:52
ELMWOOD					0:20	0:20		0:30	0:30		0:50	0:50
	1	8:10	3:49		8:30	4:09		8:40	4:19		9:00	4:39
	2	8:09	3:38		8:29	3:58		8:39	4:08		8:59	4:28
	3	8:15	3:28		8:35	3:48		8:45	3:58		9:05	4:18
	4	8:18	3:22		8:38	3:42		8:48	3:52		9:08	4:12
	5	8:13	3:31		8:33	3:51		8:43	4:01		9:03	4:21
	6	8:05	3:38		8:25	3:58		8:35	4:08		8:55	4:28
	7	8:11	3:37		8:31	3:57		8:41	4:07		9:01	4:27
	8	8:10	3:29		8:30	3:49		8:40	3:59		9:00	4:19
	9	8:12	3:29		8:32	3:49		8:42	3:59		9:02	4:19
	10	8:12	3:32		8:32	3:52		8:42	4:02		9:02	4:22
MB 3		8:08	3:26		8:28	3:46		8:38	3:56		8:58	4:16

KEY

Earliest Pickup

Latest Drop Off

8.5 Push Tables of Information

Earliest, Latest Per School

BY SCHOOL – 20 Minutes	Earliest Pick Up (Time)	Latest Drop Off (Time)
Jr/Sr High School	6:54 AM	2:53 PM
Shaw Elementry	7:40 AM	3:31 PM
Elmwood Street School	8:25 AM	4:09 PM

BY SCHOOL – 30 Minutes	Earliest Pick Up (Time)	Latest Drop Off (Time)
Jr/Sr High School	7:04 AM	3:03 PM
Shaw Elementry	7:50 AM	3:41 PM
Elmwood Street School	8:35 AM	4:19 PM

BY SCHOOL – 50 Minutes	Earliest Pick Up (Time)	Latest Drop Off (Time)
Jr/Sr High School	7:24 AM	3:23 PM
Shaw Elementry	8:10 AM	4:01 PM
Elmwood Street School	8:55 AM	4:39 PM

BY BUS	Earliest Pick Up (Bus)	Latest Drop Off (Bus)
Jr/Sr High School	7	Mini Bus 3
Shaw Elementry	2	1
Elmwood Street School	6	1

Original Minutes by Bus

ORIGINAL						
Bus #1	**Earliest Pick Up**	**Latest Drop Off**		**Bus #7**	**Earliest Pick Up**	**Latest Drop Off**
Jr/Sr High School	6:45 AM	2:30 PM		Jr/Sr High School	6:34 AM	2:32 PM
Shaw Elementry	7:26 AM	3:11 PM		Shaw Elementry	7:20 AM	3:03 PM
Elmwood Street School	8:10 AM	3:49 PM		Elmwood Street School	8:11 AM	3:37 PM
Bus #2	**Earliest Pick Up**	**Latest Drop Off**		**Bus #8**	**Earliest Pick Up**	**Latest Drop Off**
Jr/Sr High School	6:41 AM	2:25 PM		Jr/Sr High School	6:45 AM	2:24 PM
Shaw Elementry	7:20 AM	3:04 PM		Shaw Elementry	7:33 AM	2:49 PM
Elmwood Street School	8:09 AM	3:38 PM		Elmwood Street School	8:10 AM	3:29 PM
Bus #3	**Earliest Pick Up**	**Latest Drop Off**		**Bus #9**	**Earliest Pick Up**	**Latest Drop Off**
Jr/Sr High School	6:45 AM	2:20 PM		Jr/Sr High School	6:57 AM	2:16 PM
Shaw Elementry	7:25 AM	2:49 PM		Shaw Elementry	7:25 AM	3:01 PM
Elmwood Street School	8:15 AM	3:28 PM		Elmwood Street School	8:12 AM	3:29 PM
Bus #4	**Earliest Pick Up**	**Latest Drop Off**		**Bus #10**	**Earliest Pick Up**	**Latest Drop Off**
Jr/Sr High School	6:59 AM	2:17 PM		Jr/Sr High School	6:42 AM	2:31 PM
Shaw Elementry	7:31 AM	2:50 PM		Shaw Elementry	7:23 AM	3:04 PM
Elmwood Street School	8:18 AM	3:22 PM		Elmwood Street School	8:12 AM	3:32 PM
Bus #5	**Earliest Pick Up**	**Latest Drop Off**		**Mini Bus #3**	**Earliest Pick Up**	**Latest Drop Off**
Jr/Sr High School	6:57 AM	2:19 PM		Jr/Sr High School	6:40 AM	2:33 PM
Shaw Elementry	7:34 AM	3:05 PM		Shaw Elementry	7:20 AM	3:02 PM
Elmwood Street School	8:13 AM	3:31 PM		Elmwood Street School	8:08 AM	3:26 PM
Bus #6	**Earliest Pick Up**	**Latest Drop Off**				
Jr/Sr High School	6:56 AM	2:16 PM				
Shaw Elementry	7:31 AM	2:50 PM				
Elmwood Street School	8:05 AM	3:38 PM				

20 Minutes by Bus

20 Minutes

Bus 1	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:05 AM	2:50 PM
Shaw Elementry	7:46 AM	3:31 PM
Elmwood Street School	8:30 AM	4:09 PM

Bus 2	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:01 AM	2:45 PM
Shaw Elementry	7:40 AM	3:24 PM
Elmwood Street School	8:29 AM	3:58 PM

Bus 3	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:05 AM	2:40 PM
Shaw Elementry	7:45 AM	3:09 PM
Elmwood Street School	8:35 AM	3:48 PM

Bus 4	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:19 AM	2:37 PM
Shaw Elementry	7:51 AM	3:10 PM
Elmwood Street School	8:38 AM	3:42 PM

Bus 5	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:17 AM	2:39 PM
Shaw Elementry	7:54 AM	3:25 PM
Elmwood Street School	8:33 AM	3:51 PM

Bus 6	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:16 AM	2:36 PM
Shaw Elementry	7:51 AM	3:10 PM
Elmwood Street School	8:25 AM	3:58 PM

Bus 7	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	6:54 AM	2:52 PM
Shaw Elementry	7:40 AM	3:23 PM
Elmwood Street School	8:31 AM	3:57 PM

Bus 8	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:05 AM	2:44 PM
Shaw Elementry	7:53 AM	3:09 PM
Elmwood Street School	8:30 AM	3:49 PM

Bus 9	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:17 AM	2:36 PM
Shaw Elementry	7:45 AM	3:21 PM
Elmwood Street School	8:32 AM	3:49 PM

Bus 10	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:02 AM	2:51 PM
Shaw Elementry	7:43 AM	3:24 PM
Elmwood Street School	8:32 PM	3:52 AM

Mini Bus B	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:00 AM	2:53 PM
Shaw Elementry	7:40 AM	3:22 PM
Elmwood Street School	8:28 AM	3:46 PM

30 Minutes by Bus

30 Minutes

Bus 1	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:15 AM	3:00 PM
Shaw Elementry	7:56 AM	3:41 PM
Elmwood Street School	8:40 AM	4:19 PM

Bus 2	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:11 AM	2:55 PM
Shaw Elementry	7:50 AM	3:34 PM
Elmwood Street School	8:39 AM	4:08 PM

Bus 3	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:15 AM	2:50 PM
Shaw Elementry	7:55 AM	3:19 PM
Elmwood Street School	8:45 AM	3:58 PM

Bus 4	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:29 AM	2:47 PM
Shaw Elementry	8:01 AM	3:20 PM
Elmwood Street School	8:48 AM	3:52 PM

Bus 5	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:27 AM	2:49 PM
Shaw Elementry	8:04 AM	3:35 PM
Elmwood Street School	8:43 AM	4:01 PM

Bus 6	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:26 AM	2:46 PM
Shaw Elementry	8:01 AM	3:20 PM
Elmwood Street School	8:35 AM	4:08 PM

Bus 7	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:04 AM	3:02 PM
Shaw Elementry	7:50 AM	3:33 PM
Elmwood Street School	8:41 AM	4:07 PM

Bus 8	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:15 AM	2:54 PM
Shaw Elementry	8:03 AM	3:19 PM
Elmwood Street School	8:40 AM	3:59 PM

Bus 9	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:27 AM	2:46 PM
Shaw Elementry	7:55 AM	3:31 PM
Elmwood Street School	8:42 AM	3:39 PM

Bus 10	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:12 AM	3:01 PM
Shaw Elementry	7:53 AM	3:34 PM
Elmwood Street School	8:42 AM	4:02 PM

Mini Bus 3	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:10 AM	3:03 PM
Shaw Elementry	7:50 AM	3:32 PM
Elmwood Street School	8:38 AM	3:56 PM

50 Minutes by Bus

50 Minutes

Bus 1	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:35 AM	3:20 PM
Shaw Elementry	8:16 AM	4:01 PM
Elmwood Street School	9:00 AM	4:39 PM

Bus 2	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:31 AM	3:15 PM
Shaw Elementry	8:10 AM	3:54 PM
Elmwood Street School	8:59 AM	4:28 PM

Bus 3	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:35 AM	3:10 PM
Shaw Elementry	8:15 AM	3:39 PM
Elmwood Street School	9:05 AM	4:18 PM

Bus 4	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:49 AM	3:07 PM
Shaw Elementry	8:21 AM	3:40 PM
Elmwood Street School	9:08 AM	4:12 PM

Bus 5	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:47 AM	3:09 PM
Shaw Elementry	8:24 AM	3:55 PM
Elmwood Street School	9:03 AM	4:21 PM

Bus 6	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:46 AM	3:06 PM
Shaw Elementry	8:21 AM	3:40 PM
Elmwood Street School	8:55 AM	4:28 PM

Bus 7	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:24 AM	3:22 PM
Shaw Elementry	8:10 AM	3:53 PM
Elmwood Street School	9:01 AM	4:27 PM

Bus 8	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:35 AM	3:14 PM
Shaw Elementry	8:23 AM	3:39 PM
Elmwood Street School	9:00 AM	4:19 PM

Bus 9	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:47 AM	3:06 PM
Shaw Elementry	8:15 AM	3:51 PM
Elmwood Street School	9:02 AM	4:19 PM

Bus 10	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:32 AM	3:21 PM
Shaw Elementry	8:13 AM	3:54 PM
Elmwood Street School	9:02 AM	4:22 PM

Mini Bus 48	Earliest Pick Up	Latest Drop Off
Jr/Sr High School	7:30 AM	3:23 PM
Shaw Elementry	8:10 AM	3:52 PM
Elmwood Street School	8:58 AM	4:16 PM

8.6. Capacity Calculations

BUS #	High School		Shaw	Elmwwod
1	66	#		45
2	60	#		50
3	68	#		77
4	66	#		60
5	68	#		56
6	67	#		50
7	51	#		36
8	50	#		30
9	63	#		67
10	57	#		38
Mini 3	16	#		14

This is the student counts from the drivers

BUS #		High School		Shaw		Elmwwod	
1	AM	35		29		33	0.805556
	PM	30		29		31	
2	AM	30		27		28	0.771429
	PM	28		27		30	
3	AM	38		38		49	0.808511
	PM	38		30		42	
4	AM	29		33		28	0.851852
	PM	32		46		31	
5	AM	39		49		38	0.844828
	PM	38		48		27	
6	AM	35		35		31	0.714286
	PM	38		32		30	
7	AM	15		20		12	0.714286
	PM	23		20		10	
8	AM	22		26		12	0.896552
	PM	30		23		12	
9	AM	29		32		33	
	PM	43		34		45	0.708333
10	AM	49		32		29	
	PM	49		34		22	
Mini 3	AM	11		14		11	1
	PM	9		9		8	
				352		321	
				432		523	
				0.814815		0.613767	
				Shaw		Elmwood	

8.7. Reduce Cost Calculations

COST DIFFERENTIAL

Utilizing Same MHS Bus Routes

For 2019-2020 School Year this option would have cost Millbury:

$411(11) + $28.64(11) + 1($411) + 1($50.35) = $4566.61

$4,66.61/day * 182 days = **$831,123.02 total**

Currently (2019-2020) - **$815,542 total**

Difference:

$831,123.02 - $815,542 = **$15,581.02 per year**

Increase in budget of 1.9%

Combining Mini/Bus 7 MHS Routes

For 2019-2020 School Year this option would have cost Millbury:

$411(10) + $28.64(10) + 2($411) + 2($50.35) = $4,544.90

$4,544.90/day * 182 days = **$827,171.80 total**

Currently (2019-2020)- **$815,542 total**

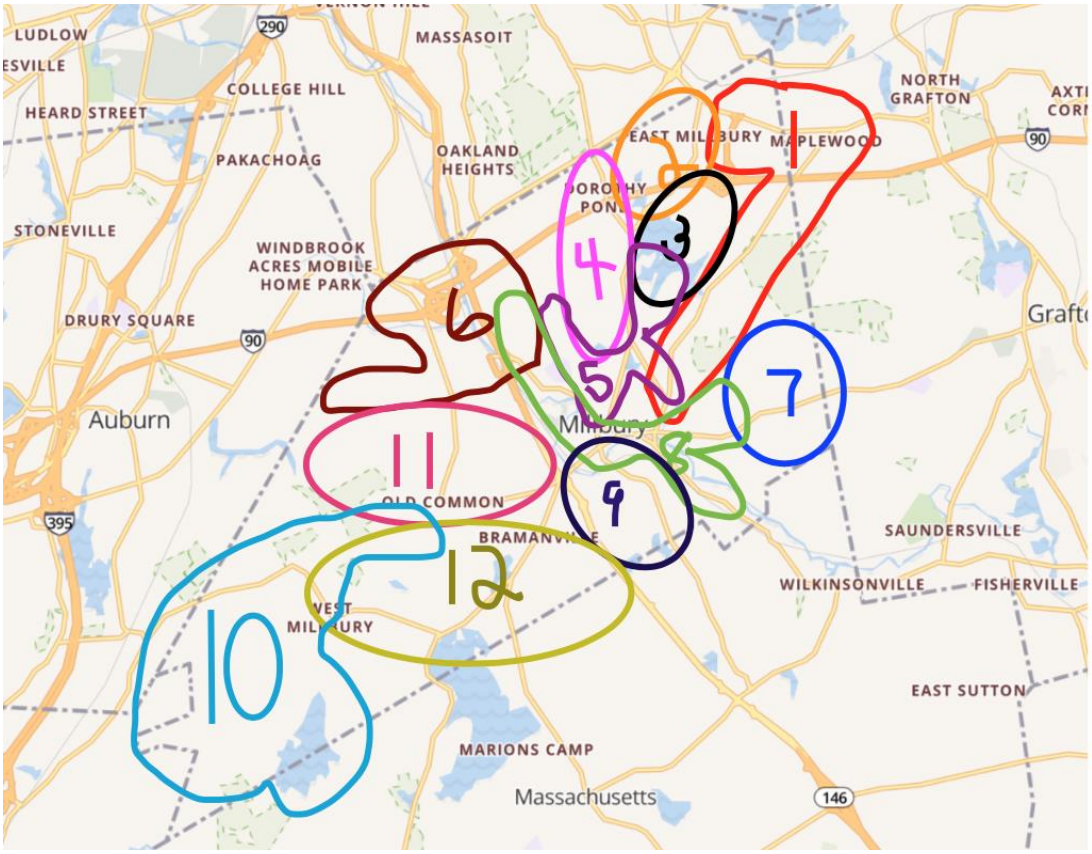
Difference:

$827,171.80 - $815,542 = **$15,581.02 per year**

Increase in budget of 1.4%

*If an additional Special Education Bus needed to be purchased, Budget would increase by $84,613.62 or 9.37%

8.8 Bus Route Sections on Map of Millbury



8.9 Individual Route Pages

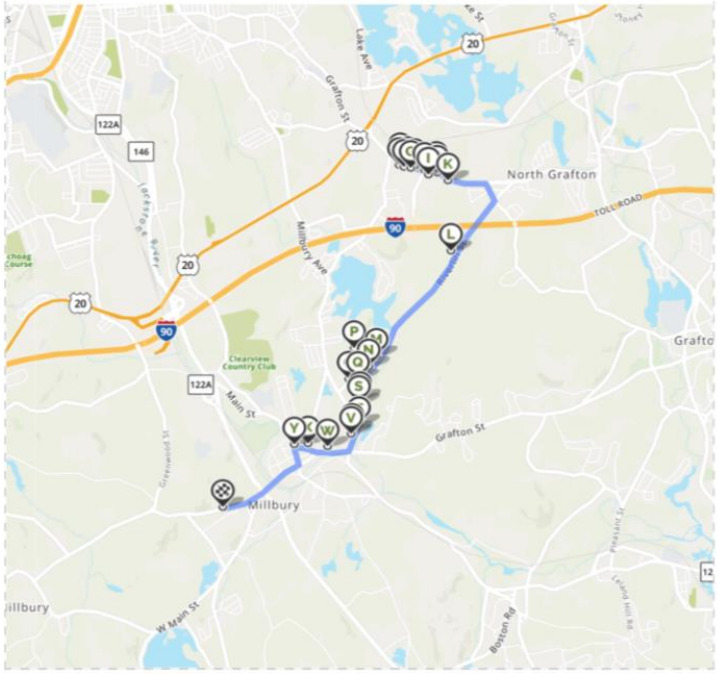
Bus 1

BUS 1 Route

15 Minutes Driving Time; 6.4 Miles

	Stop	Number of Students Picked Up	
1	1527 Grafton RD	1	A
2	Abbot Place	3	B
3	Ellenwood RD	5	C
4	Ackerman RD	3	D *Assumption Student
	TURN AROUND AT SCLAMO'S APPLIANCE/FURNITURE		
5	1482 Grafton RD	1	E
6	Grafton RD @ Middleton St	6	F
7	Grafton RD @ Raymond St.	2	G
8	Grafton @ Oakes St.	2	H
9	1516 Grafton RD.	1	I
10	Grafton @ Cedar Ave	5	j
11	Grafton @ Hastings Ave	2	K
	TURN RIGHT ONTO DEERNOLM STREET		
	CONTINUE ONTO RIVERLIN STREET		
12	284 Riverlin	2	
13	282 Riverlin	1	
14	257 Riverlin	1	L
15	240 Riverlin	2	
16	Riverlin @ Colton Road	3	M
17	149 Riverlin	2	
18	142 Riverlin	1	
19	Riverlin @ Riverlin PKWY	3	N
	TURN RIGHT ONTO RAILROAD AVE		
20	Railroad Ave @ Gover RD	1	O
	TURN RIGHT ONTO GOVER ROAD		
	TURN AROUND AT CUL DE SAC		
21	25 Gover	3	P
22	18 Gover	3	
	TURN LEFT ONTO RAILROAD AVE		
	TURN RIGHT ONTO RIVERLIN ST		
24	130 Riverlin	1	
25	127 Riverlin	1	Q
26	119 Riverlin	1	
27	107 Riverlin	1	
28	Riverlin @ Brightside Ave	3	R
29	Riverlin @ Blanchard	1	S
30	64 Riverlin	1	T
31	Riverlin St @ Mayfair Drive	6	U
32	Riverlin @ Williams St.	1	V
33	20 Riverlin	1	
	TURN RIGHT ONTO CANAL ST.		
34	65 Canal St (Cordis Mills)	1	W
	TURN RIGHT AT CVS		
	EAR RIGHT TO STAY ON CANAL STREE		
35	Canal St @ Railroad CT	1	X
36	3 Canal St	1	Y
	TURN LEFT ONTO MAIN ST		
	TURN RIGHT ONTO ELM STREET		
	ELM STREET TURNS INTO ELMWOOD ST.		
37	Shaw Elementry School		GOAL
38	Elmwood St. School		
39	Assumption School		
	Total Students	**73**	
	Capacity Percentage	**95%**	

*Assumption Student



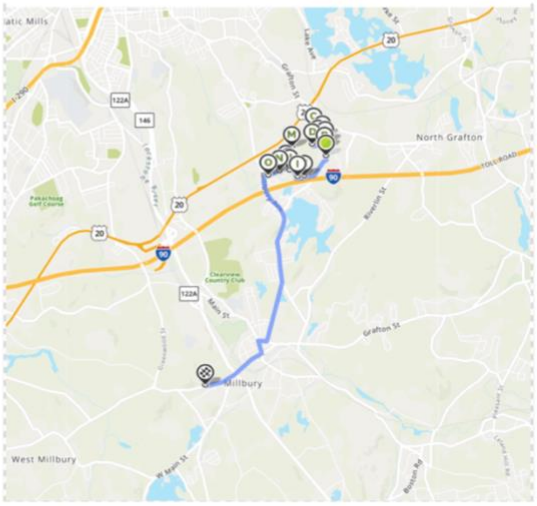
Minutes	30 Second Times	Stops	Est. Time
15	25	36	900
			15
			30

Bus 2

BUS 2 Route

20 Minutes Driving Time; 6.9 Miles

	Stop	Number of Students Picked Up		
1	Wheelock Ave @ John St	6	A	*Assumption Student
2	Wheelock Ave @ Marion Ave	6	B	
	TURN LEFT ONTO GRAFTON RAOD			
	TURN LEFT ONTO WARD AVE			
	TURN RIGHT ONTO KATHERINE ST			
	TURN LEFT ONTO BARBARA AVE			
3	Barbara St. @ Shirley Ave	2	C	
	TURN LEFT ONTO SHIRELY AVE			
	TURN RIGHT ONTO HILLTOP			
4	19 Hilltop Dr.	3	D	
	TURN LEFT ONTO SHIRELY AVE			
5	15 Shirley Ave	5	E	
	CONTINUE ONTO BARBARA AVE			
	TURN RIGHT ONTO KATHERINE ST			
	TURN LEFT ONTO WARD ST			
	TURN RIGHT ONTO GRAFTON ROAD			
	TURN RIGHT ONTO WHEELOCK AVE			
6	193 Wheelock	1	F	
7	187 Wheelock	1		
8	184 Wheelock	1	G	
	TURN RIGHT ONTO OAK POND AVE			
9	Oak Pond Ave @ Overlook Ave	18	H	
10	Oak Pond @ Westview Ave	11	I	
11	52 Oak Pond	1	j	
12	50 Oak Pond	2	K	
13	Skyview Drive @ Oak Pond	7	L	
	TURN RIGHT ONTO SKYVIEW DRIVE			
14	Nightview Place at Skyview Drive (37 Skyview Dr.)	6	M	
	TURN RIGHT ONTO NIGHTVIEW PLACE			
	TURN LEFT ONTO SKYVIEW DRIVE			
	TURN RIGHT ONTO OAK POND AVE			
15	Oak Pond Ave @ Pineland Ave	2	N	*Assumption Student
16	Oak Pond @ Broadmeadow Ave	3	O	
	TURN LEFT ONTO MILLBURY AVE			
	CONTINUE ONTO HOWE AVE			
	TURN RIGHT ONTO CANAL STREET			
	TURN LEFT ONTO MAIN ST			
	TURN RIGHT ONTO ELM STREET			
	ELM STREET TURNS INTO ELMWOOD ST.			
17	Shaw Elementry School		GOAL	
18	Elmwood St. School			
19	Assumption School			
	Total Students	**75**		
	Capacity Percentage	**97%**		



Minutes	30 Second Times per stop	Stops	Est. Time
20	25	16	400
			6.666666667
			26.66666667

Bus 3

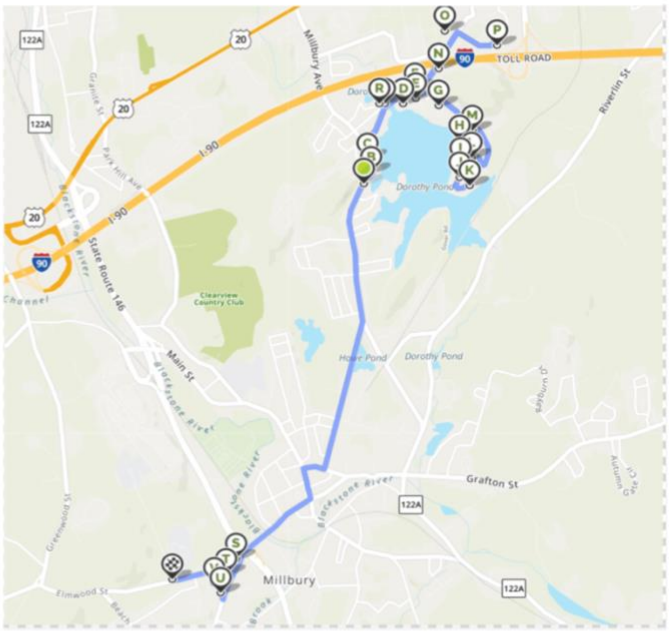
BUS 3 Route

19 Minutes Driving Time; 6.7 Miles

	Stop	Number of Students Picked Up	
1	188 Millbury Ave	2	A
2	Millbury Ave @ Shore Terrace	4	B
3	Millbury Ave @ Dorothy Landing	3	C
	TURN RIGHT ONTO WHEELOCK AVE		
4	Wheelock @ Cristo Ln	3	D
5	Wheelock @ Lakeview Road	3	E
6	Wheelock @ Margaret St	2	F
	TURN RIGHT ONTO MACATHUR DRIVE		
7	MacArthur Dr @ Tiffany Circle	12	G
8	MacArthur Dr @ Montgomery Dr	8	H
9	67 MacArthur	3	I
10	85 MacArthur	4	J
11	118 MacArthur	2	K
12	Montgomery Dr @ Rollie Shepard Dr.	2	L
	TURN RIGHT ONTO ROLLIE SHEPARD DRIVE		
13	Rollie Shepard Dr. @ Bill Graham Ln	4	M
	TURN RIGHT ONTO MACATHUR DRIVE		
	TURN RIGHT ONTO WHEELOCK AVE		
14	86 Wheelock	1	N
15	Wheelock @ LT Haynes Dr.	1	O
	TURN RIGHT ONTO LT HAYNES DRIVE		
16	14 LT Haynes Dr.	15	P
	TURN AROUND; LEFT ON WHEELOCK AVE		
17	Wheelock @ Rindge St.	2	Q
18	Wheelock @ Epping St.	1	R
	TURN LEFT ONTO MILLBURY AVE		
	CONTINUE ONTO HOWE AVE		
	TURN RIGHT ONTO CANAL STREET		
	TURN LEFT ONTO MAIN ST		
	TURN RIGHT ONTO ELM STREET		
	TAKE ROTARY EXIT ONTO WEST MAIN STREET		
19	28 W. Main St.	3	S
20	40 W. Main St.	1	T
21	West Main @ Gould St.	1	U
	TURN RIGHT ONTO GOULD STREET		V
	TURN LEFT ONTO ELMWOOD ST		
22	Shaw Elementry School		GOAL
24	Elmwood St. School		
	Total Students	**77**	
	Capacity Percentage	**100%**	

Minutes	30 Second Times per st	Stops	Est. Time
19	25	21	525
			8.75
			27.75

*Assumption Student



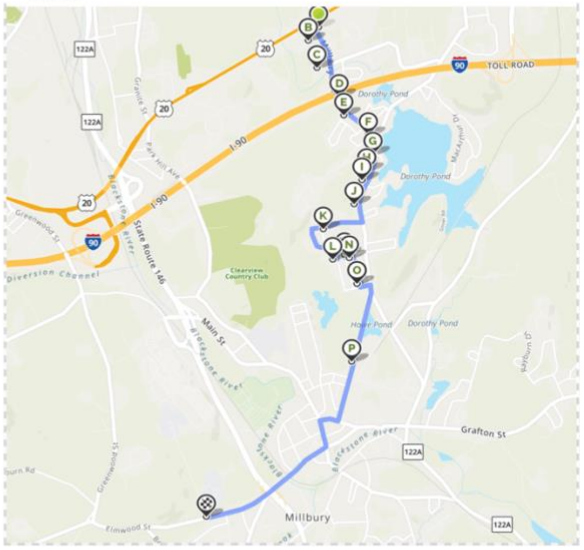
Bus 4

BUS 4 Route

10 Minutes Driving Time; 4.1 Miles

	Stop	Number of Students Picked Up		
1	328 Milbury Ave	1	A	*Assumption Student
2	Millbury Ave @ Millbury Terrace	1	B	
3	Millbury Ave @ Glen Ave	1	C	
4	274 Millbury Ave	2	D	
5	Millbury Ave @ Croyden St.	8	E	*Assumption Student
6	Millbury Ave @ Woodrow Rd	9	F	
7	Millbury Ave @ Dorothy Road	8	G	
8	189 Millbury Ave	2	H	
9	185 Millbury Ave	2	I	
10	Millbury Ave @ Wilson Road	5	j	
	TURN RIGHT ONTO HAYWARD GLEN DRIVE			
11	Hayward Glen Dr. @ Augusta Dr.	18	K	*Assumption Student
	TURN LEFT ONTO WINGFOOT LANE			
12	Maple Lane @ Linda Ave	1	L	(37 Linda Ave)
	TURN LEFT ONTO MAPLE LANE			
13	Maple Lane @ Howe Lane	7	M	
14	Maple Lane @ Jackson Lane	5	N	
	TURN RIGHT ONTO JACKSON LANE			
15	Linda Ave @ Jackson Lane	3	O	
	TURN LEFT ONTO LINDA AVE			
	TURN RIGHT ONTO MILLBURY AVE; CONTINUE ONTO HOWE AVE			
16	Howe Ave @ Cobbleston Village Way	1	P	
17	47 Howe Ave	1		
18	45 Howe Ave	1		
19	Howe Ave @ Atwood St.	1		
	TURN RIGHT ONTO CANAL STREET			
	TURN LEFT ONTO MAIN ST			
	TURN RIGHT ONTO ELM STREET			
	ELM STREET TURNS INTO ELMWOOD ST.			
20	Shaw Elementry School	GOAL	Q	
21	Elmwood St. School			
22	Assumption School			

*Moniter



Total Students	**77**
Capacity Percentage	**100%**

Minutes	30 Second Times per s	Stops	Est. Time
10	25	19	475
			7.916666667
			17.91666667

Bus 5

BUS 5 Route

18 Minutes Driving Time; 6.1 Miles

	Stop	Number of Students Picked Up
1	4/5 Millbury Ave	5
2	26 Millbury Ave	2
3	34 Millbury Ave	2
4	60 Millbury Ave	3
5	68 Millbury Ave (Woodside Apartments)	9
	BEAR RIGHT CONTINUE ONTO MILLBURY AVE	
6	Millbury Ave @ Lake St.	11
7	Millbury Ave @ Oak St.	3
8	134 Millbury Ave	1
9	Millbury Ave @ Hayward LN	4
	TURN RIGHT ONTO WILSON ROAD	
10	Wilson @ Manor	6
	TURN LEFT ONTO MANOR ROAD	
11	Manor Rd. @ Millbury Ave	1
	TURN LEFT ONTO MILLBURY AVE	
	BEAR RIGHT ONTO HOWE AVE	
	TURN LEFT ONTO CANAL ST.	
	TURN RIGHT ONTO ELM ST.	
12	13 Elm St.	1
13	34 Elm St.	6
	TURN RIGHT ONTO MAIN ST.	
	TURN RIGHT ONTO MILES ST.	
14	19 Miles St.	3
	TURN RIGHT ONTO HAMILTON ST.	
15	Hamilton St. @ Atwood Ave	4
	TURN LEFT ONTO PARK ST.	
16	Lincoln Ave @ Park St	4
	TURN LEFT ONTO LINCOLN AVE	
	TURN RIGHT ONTO MILES ST.	
17	70 Miles St	1
18	76 Miles St	1
19	87/88 Miles St	3
	TURN LEFT ONTO LEONE AVE	
20	Prospect St @ Budreau Ave	1
21	Prospect St @ Lindy St	1
22	25 Prospect St	1
23	7 Prospect St	1
	TURN RIGHT ONTO HAMILTON ST.	
	TURN LEFT ONTO MAIN ST.	
	TURN RIGHT ONTO WEST ST.	
24	West @ Cherry St.	3
	TURN RIGHT ONTO ELM ST.	
	ELM STREET TURNS INTO ELMWOOD ST.	
25	Shaw Elementry School	
26	Elmwood St. School	
27	Assumption School	
	Total Students	**77**
	Capacity Percentage	**100%**

Minutes	30 Second Times	Stops	Est. Time
18	25	24	600
			10
			28

A *Assumption Student

B

C *Assumption Student

D

E *Assumption Student

F

G

H

I

jKL

M

N

O

P

Q

R

S

T

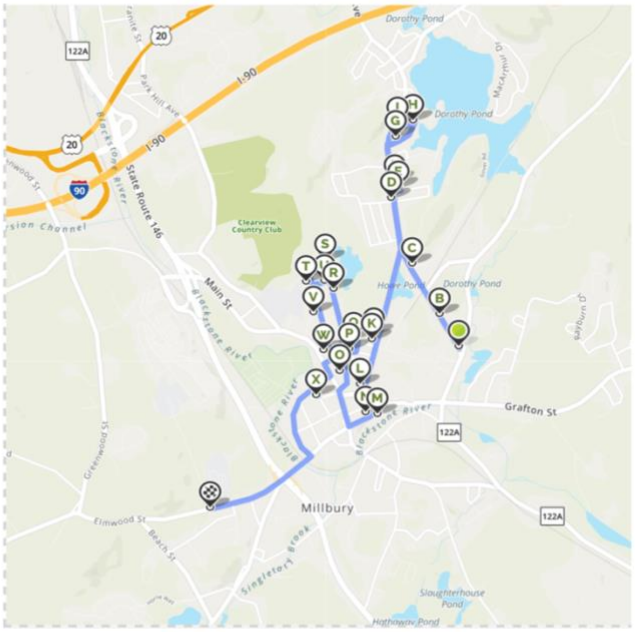
U

V

W

X

GOAL



Bus 6

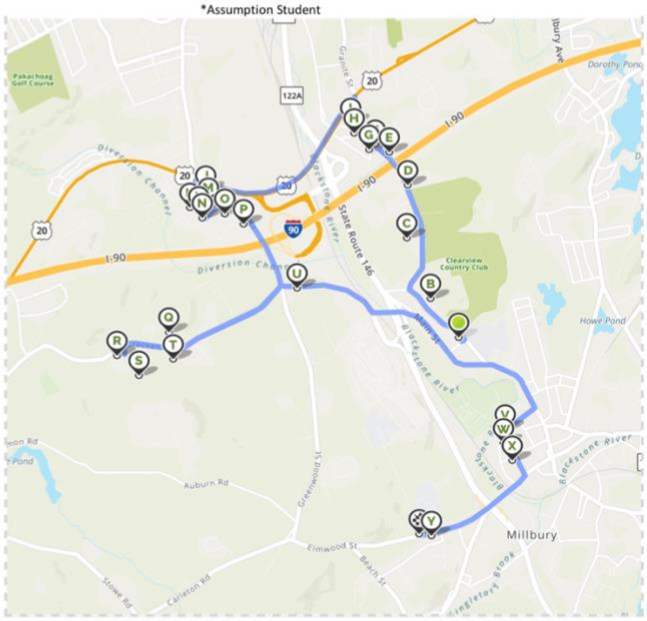
BUS 6 Route

21 Minutes Driving Time; 8.4 Miles

	Stop	Number of Students Picked Up	
1	Martin St. @ Dewey Ave	2	A
2	29 Martin St.	1	
3	40 Martin St.	1	
4	44 Martin St.	1	
5	54 Martin St.	1	B
	TURN RIGHT ONTO PARK HILL AVE		
6	27 Park Hill Ave	2	
7	53 Park Hill Ave	1	C
8	Park Hill Ave @ Weldon Dr.	2	D
9	Park Hill Ave @ Primrose LN	6	E
10	Park Hill Ave @ Azalea Circle	1	F
11	Park Hill Ave @ Hollywood Ave	3	G
12	Park Hill Ave @ Heather Ave	1	H
13	Park Hill Ave @ Johnson St.	8	I
14	148 Park Hill Ave	1	
	TURN LEFT ONTO ROUTE 20		
	TURN LEFT ONTO GREENWOOD STREET		
15	351 Greenwood St (for 353 Greenwood)	2	J
	TURN RIGHT ONTO HAWTHORNE STREET		
16	Border Ave @ Hawthorne St.	7	K
	TURN LEFT ONTO BORDER AVE		
17	Border Ave @ Elmwood Ave	4	L
	TURN LEFT ONTO ELMWOOD AVE		
18	3 Elmwood Ave	3	M
	TURN RIGHT ONTO GREENWOOD STREET		
19	Roger St @ Greenwood St.	1	N
20	360 Greenwood St.	2	O
21	Chunis Ave @ Greenwood St.	1	P
	TURN RIGHT ONTO MCCRACKEN ROAD		
22	82 McCracken	2	Q
24	92 McCracken	2	
25	Hidden Meadow @ McCracken Rd.	3	R/S
	TURN AROUND AT END HIDDEN MEADOW		
	TURN RIGHT ONTO MCCRACKEN ROAD		
26	75 McCracken	3	T
27	67 McCracken	1	
28	27 McCracken	1	U
	TURN LEFT ONTO MAIN ST.		
	TURN RIGHT ONTO WEST STREET		
29	West St @ Waters St.	3	V
	TURN LEFT ONTO WATERS ST.		
30	Grove St @ Waters St.	9	W/X
	TURN LEFT ONTO ELM ST; TURNS INTO ELMWOOD ST		
31	47 Elmwood St.	1	Y
32	Shaw Elementry School		GOAL
33	Elmwood St. School		
	Total Students	**76**	
	Capacity Percentage	**99%**	

Minutes	30 Second Times per stop	Stops	Est. Time
21	25	31	775
			12.91666667
			33.91666667

*Assumption Student



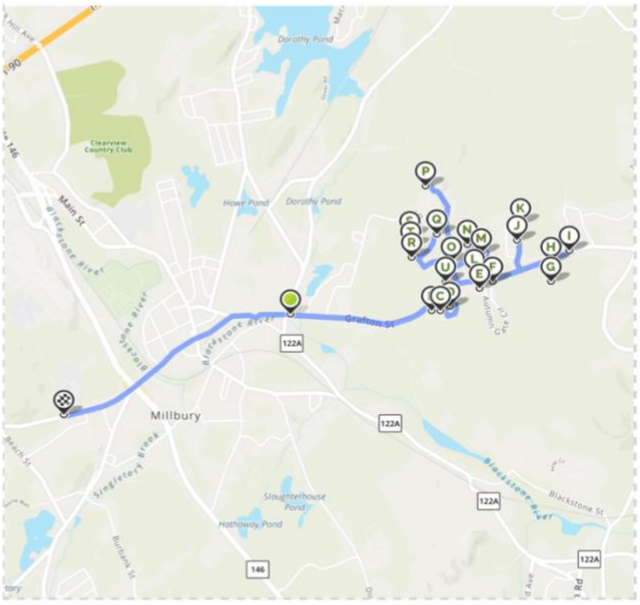
Bus 7

BUS 7 Route

20 Minutes Driving Time; 6.7 Miles

	Stop	Number of Students Picked Up	
1	4 Grafton St	DAYCARE	A
2	84 Grafton St	1	B
	TURN RIGHT ONTO JONATHAN AVE		
3	Momin Dr. @ Jonathan Dr.	2	C/D
	CONTINUE AROUND SEMI-CIRCLE ON MOMIN DRIVE		
4	Autumn Gates Circle (Both Entrances)	13	E/F
5	144 Grafton St.	1	G
6	148 Grafton St.	1	H
	TURN AROUND IN SEAN MIKEAL WAY (GRAFTON)		I
	TURN RIGHT ONTO BUNKER HILL RD		
	STOP AT SHED; APPROXIMATELY 65 BUNKER HILL ROAD		
7	Bunker Hill Rd @ "THE SHED"	6	J
	BACK INTO CONCORD HILL TO TURN AROUND		K
	TURN LEFT ONTO BUNKER HILL RD		
	TURN RIGHT ONTO GRAFTON ST.		
	TURN RIGHT ONTO PHEASENT HILL ROAD		
8	1 Pheasent Hill Rd	1	L
9	Coldbrook Rd @ Turning Leaf	2	M
10	Coldbrook Rd @ Woodridge Rd	9	N
	TURN LEFT ONTO WOODRIDGE ROAD		
11	Braney Rd @ Coldbrook Rd	7	O
	TURN LEFT ONTO COLDBROOK ROAD		
	TURN RIGHT ONTO BRANEY ROAD		
	TURN LEFT ONTO CRONIN BROOK WAY		
12	Cronin Brook Way @ Diana Hill Rd	20	P
	BACK INTO DIANA HILL ROAD TO TURN AROUND		
	TURN RIGHT ONTO BRANEY ROAD		
	TURN RIGHT ONTO DANIELLE DRIVE		
13	12 / 16 Danielle Dr.	3	Q
14	Rayburn Drive @ Danielle Dr.	2	R
	TURN RIGHT ONTO RAYBURN DRIVE		
15	Rayburn @ 2 Horseshoe Lane	5	S
	LOOP AROUND HORSESHOE LANE		T
	TURN LEFT ONTO LISA DRIVE		
	TURN RIGHT ON BRANEY ROAD		
	TURN RIGHT ON GRAFTON STREET		
16	97 Grafton St.	1	U
17	Shaw Elementry School		GOAL
18	Elmwood St. School		
	Total Students	**74**	
	Capacity Percentage	**96%**	

Minutes	30 Second Times per stop	Stops	Est. Time
20	25	16	400
			6.666666667
			26.66666667



Bus 8

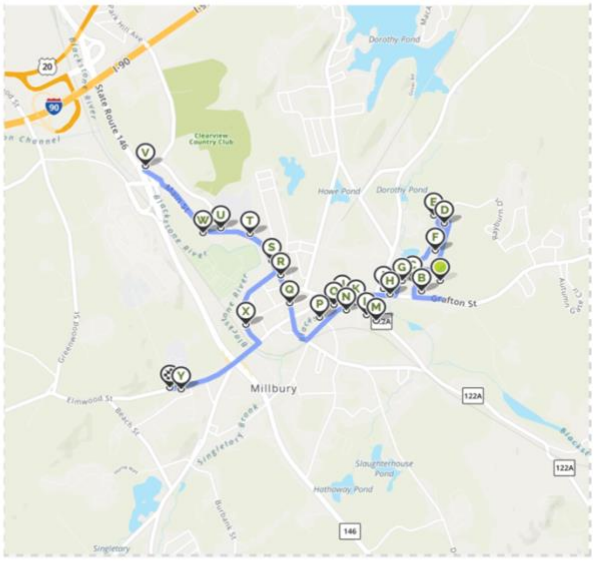
BUS 8 Route

15 Minutes Driving Time; 5.9 Miles

	Stop	Number of Students Picked Up	
1	39 Grafton St	2	A
2	Grafton @ Memorial Dr.	16	B
	TURN RIGHT ONTO CAROUSEL DR.		
3	10/12 Carousel Dr.	3	C
4	Carousel Dr. @ Rayburn	2	D/E
	GO AROUND ROTARY		
5	Carousel Dr. @ Cheryl LN	11	F
6	12 Bellville LN	2	GOAL
7	Grafton St. @ Bellville LN	1	H
8	5 Grafton St	1	I
	CONTINUE ONTO CANAL STREET		j
	AT END, TURN LEFT ONTO 122A/ PROVIDENCE STREET		
9	Providence St @ Pearl St.	4	K
10	18 Providence St.	1	L
	CONTINUE TO DIRT BEFORE AQUARION WATER CO. AT 24 PROVIDENCE ST.		M
	TURN AROUND IN DIRT.		
	TURN LEFT ON MAPLE STREET		
11	48 Maple St.	4	N
12	Maple St. @ Coral St.	3	O
13	Maple St. @ Curve St.	3	P
	TURN RIGHT ON SOUTH MAIN STREET		
	CONTINUE THROUGH INTERSECTION		
14	Main St. @ Church St.	6	Q
15	58 Main St.	3	R
16	Main St. @ Hamilton St.	2	S
17	Main St. @ Orchard St.	3	T
18	150 N. Main St.	1	U
19	228 N. Main St.	1	V
	TURN AROUND. CAN USE PARK HILL AVE IF NEEDED		
20	163 N. Main St.	1	W
	TURN RIGHT ON WEST STREET		
	CONTINUE ONTO RIVER STREET		
21	24 River St.	1	X
22	18 River St.	2	
	TURN RIGHT ON ELM STREET; CONTINUE ONTO ELMWOOD		
23	Shaw Elementry School		Y/GOAL
24	Elmwood St. School		
	Total Students	**73**	
	Capacity Percentage	**95%**	

Minutes	30 Second Times	Stops	Est. Time
15	25	22	550
			9.166666667
			24.16666667

*Assumption Student



Bus 9

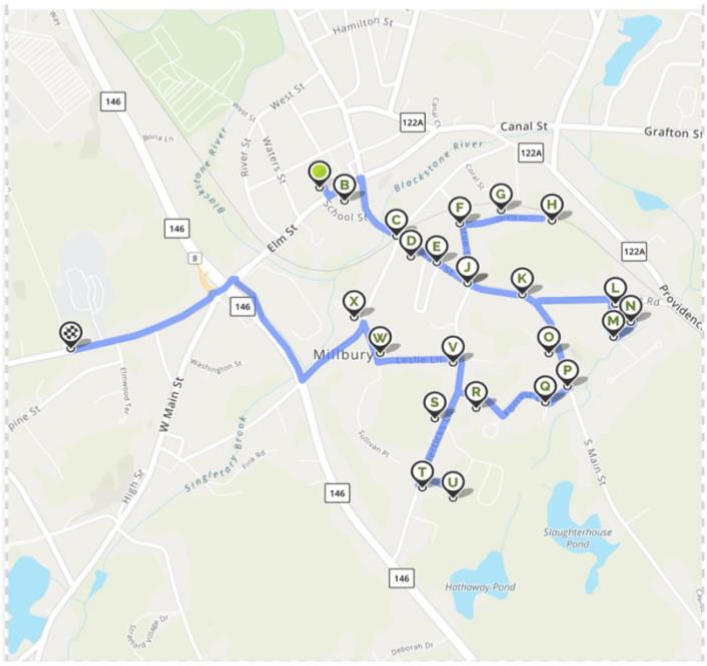
BUS 9 Route

15 Minutes Driving Time; 4.4 Miles

	Stop	Number of Students Picked Up	
1	Elm St @ School St	1	A
2	109 Elm St.	4	B
	TURN RIGHT ONTO SOUTH MAIN ST.		
3	S. Main @ Sycamore	3	C
4	34 S. Main	1	D
5	S. Main @ Fontaine St	4	E
	TURN LEFT ONTO CURVE ST. RIGHT ONTO JACKIE DR.		
6	Curve St @ Jackie Dr.	3	F
7	9 Jackie Drive	1	G
	TURN AROUND AT CUL DE SAC		H
	TURN LEFT ONTO CURVE ST. LEFT ONTO SOUTH MAIN		
8	57 S. Main	1	I
9	S. Main @ Woodland	5	J
10	69 S. Main	3	K
	BEAR LEFT ONTO RICE ROAD		
11	Rice RD @ Thomas Hill RD	1	L
12	Thomas Hill RD @ Aldrich Ave	4	M
	TURN LEFT ONTO ALDRICH AVENUE		N
	TURN LEFT ONTO RICE ROAD		
	TURN LEFT ONTO SOUTH MAIN		
13	86 S. Main	4	O
14	S. Main @ Phillips Dr.	1	P
	TURN RIGHT ONTO FORREST DRIVE		
15	Phillips Dr. @ Forrest Dr.	2	Q
	TURN RIGHT ONTO WOODLAND STREET		
16	34 Woodland St	1	R
	TURN LEFT ONTO HERRICKS LANE		
17	25 Herricks LN	2	S
18	Herricks LN @ Jessica Dr.	4	T
	TURN LEFT ONTO JESSICA J DRIVE		
19	Jessics Dr. @ Moore Dr.	4	U
	UTILIZE ROUND ABOUT		
	RIGHT ON HERRICKS LANE		
20	Woodland St. @ Leslie LN	8	V
	TURN LEFT ONTO LESLIE LANE		
21	Leslie LN @ Sullivan Pl	4	W
	TURN RIGHT ONTO W MAIN ST.		
22	Sycamore St. @ Sullivan Pl	15	X
	TURN LEFT ONTO SYCAMMOR STREET		
	TURN RIGHT ONTO 146; GET OFF EXIT		
	TURN RIGHT ONTO ELMWOOD STREET		
23	Shaw Elementry School		GOAL
24	Elmwood St. School		
25	Assumption School		
	Total Students	**76**	
	Capacity Percentage	**99%**	

Minutes	30 Second Times	Stops	Est. Time
15	25	22	550
			9.166666667
			24.16666667

*Assumption Student



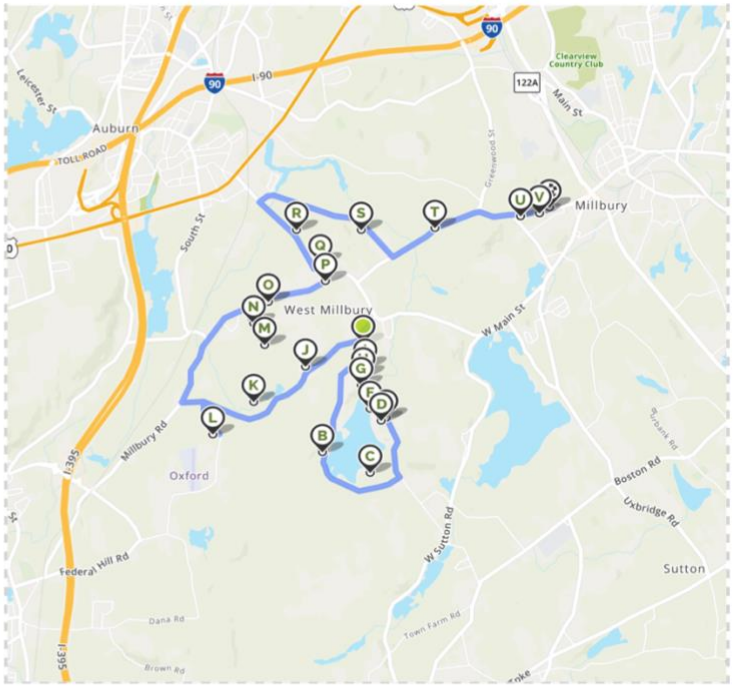
Bus 10

BUS 10 Route

31 Minutes Driving Time; Miles 12.4

	Stop	Number of Students Picked Up	
1	South Oxford @ Peggy Dr.	3	A
	TURN LEFT ON DOLAN RD.		
	TURN RIGHT ONTO DAVIS RD.		
2	3 Davis Rd.	2	
3	28 Davis	2	
4	29 Davis	2	
5	48 Davis	1	
6	58 Davis	3	B
	CONTINUE DOWN DAVIS RD ONTO GRIGGS ROAD		
	TURN LEFT AT END OF GRIGGS ROAD ONTO W. MILLBURY ROAD		C
	W. MILLBURY ROAD TURNS INTO DOLAN ROAD		
	IN CASE OF INCLEMENT WEATHER YOU CAN TURN AROUND AT 67 DAVIS INSTEAD TO ACCESS DOLAN ROAD		
7	43/46 Dolan Rd.	5	D/E
8	Dolan Rd. @ Sunset Dr.	1	F *Assumption Student
9	Dolan Rd. @ Bayberry LN	2	G *Assumption Student
10	Dolan @ Peach Tree Dr.	1	H
11	15 Dolan	2	I
	TURN LEFT ONTO SOUTH OXFORD ROAD		
12	52 S. Oxford	1	J
13	59 S. Oxford	1	
14	71 S. Oxford	2	
15	S. Oxford @ Wedgeood LN	3	
16	84 S. Oxford	2	
17	92 S. Oxford	1	
18	96 S. Oxford	1	K
	TURN LEFT ONTO FEDERAL HILL ROAD		
19	213 Federal Hill Road	2	L
	TURN AROUND IN DRIVEWAY		
	TURN LEFT ONTO OLD MILLBURY RD		
	TURN RIGHT ONTO SOUTH/BARNES STREET (AUBURN)		
	TURN RIGHT ONTO GILBERT WAY		
20	19 Gilbert Way	5	M *Assumption Student
21	13 Gilbert Way	1	
22	9 Gilbert Way	4	N
	TURN AROUND IN CUL DE SAC		
23	393 W. Main	1	O
24	382 W. Main	1	
25	376 W. Main	1	
26	372 W. Main / Backstrad	3	*Assumption Student
27	357 W. Main	1	P
	TURN LEFT ONTO STONE ROAD		
28	10 Stone Rd.	3	Q
29	16 Stone	2	
30	32/34/36 Stone @ 34 Stone	5	R
	TURN RIGHT ONTO BROOK STREET / TURNS INTO STOWE ROAD		
31	17 Stowe Rd	2	S
	TURN LEFT ONTO CARLETON ROAD		
32	49 Carleton Rd	1	
33	29 Carleton Rd	1	T
34	75 Elmwood Street	2	U
35	63 Elmwood Street	2	V
36	Shaw Elementry School		GOAL
37	Elmwood St. School		
38	Assumption School		
	Total Students	**72**	
	Capacity Percentage	**94%**	

Minutes	30 Second Times	Stops	Est. Time
31	25	35	875
			14.58333333
			45.58333333



Bus 11

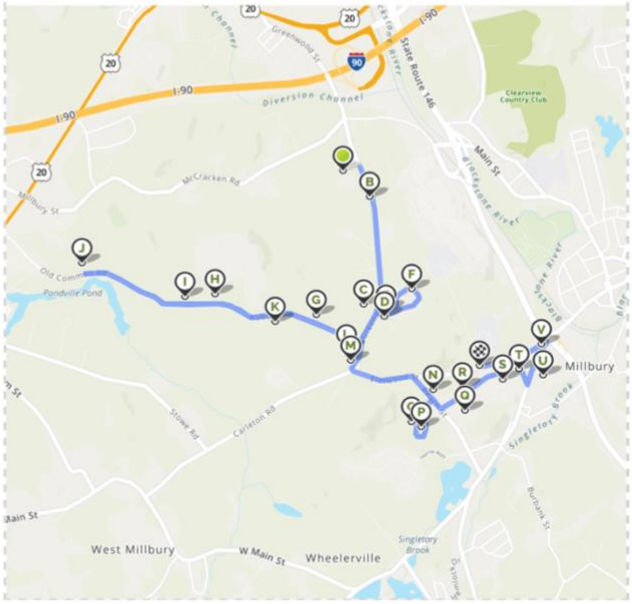
BUS 11 Route

21 Minutes Driving Time; 7.2 Miles

	Stop	Number of Students Picked Up	
1	399 1/2 Greenwood St.	3	A
2	408 Greenwood St.	1	
3	Greenwood @ Tainter Hill Rd.	1	B
4	445/448 Greenwood	2	
5	450 Greenwood	1	
6	452 Greenwood	2	C
	TURN LEFT ONTO CYNDY LN		
	TURN AROUND AT CUL DE SAC		
7	Cyndy LN @ Nicole Dr.	6	D/E/F
	TURN LEFT ON GREENWOOD		
8	463 Greenwood	1	
	RIGHT ONTO AUBURN RD.		
9	16 Auburn Rd.	1	G
10	36 Auburn	1	
11	48 Auburn	2	
12	54 Auburn	1	H
13	56 Auburn	1	
14	64 Auburn	2	I
	TURN AROUND 101 OLD COMMON IN AUBURN		J
15	31 Auburn	1	K
16	17 Auburn	2	
17	11 Auburn	2	
18	5 Auburn	1	L
	TURN RIGHT ONTO GREENWOOD		
19	9 Old Common	2	M
	TURN LEFT ONTO ELMWOOD ST.		
	TURN RIGHT ONTO BEACH ST.		
20	54 Beach St.	3	N
	TURN RIGHT ONTO BENGSTON LN		
21	4 Bengston LN	2	O
22	10 Bengston LN	1	P
	TURN RIGHT ONTO BEACH ST.		
	TURN LEFT ONTO ALPINE ST.		
23	Alpine @ Louis Ballard LN	6	Q
24	Alpine @ Todd LN	2	R
25	Alpine @ Elmwood Terrace	14	S
	TURN LEFT ONTO ELMWOOD TERRACE		
	TURN RIGHT ONTO ELMWOOD ST.		
	TURN RIGHT ONTO GOULD ST.		T
	TURN LEFT ONTO W. MAIN		
26	W Main @ Washington St	8	U
	STOP IN SECOND ROTARY		
27	Elmwood St. @ Elm Court	7	V
	CONTINUE ROTARY BACK TO ELMWOOD ST.		
28	Shaw Elementry School		GOAL
29	Elmwood St. School		
30	Assumption St. School		
	Total Students	**76**	
	Capacity Percentage	**99%**	

*Assumption Student

Minutes	30 Second Times	Stops	Est. Time
21	25	27	675
			11.25
			32.25



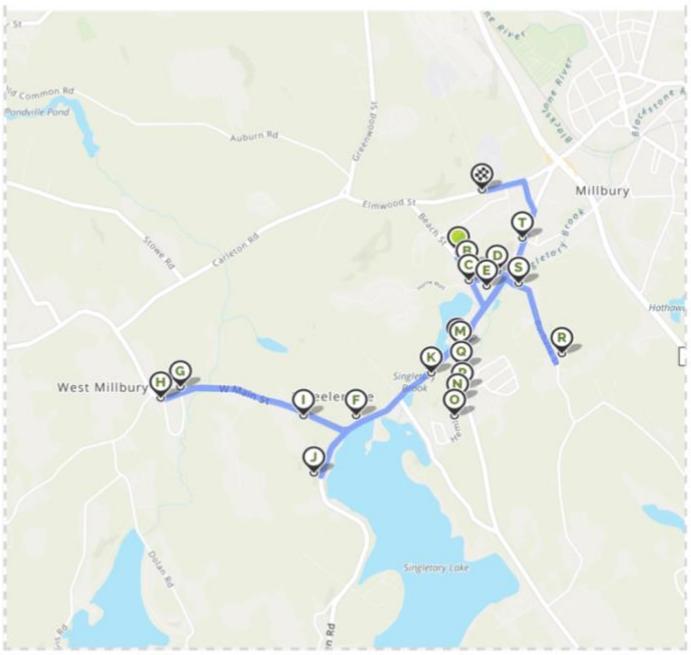
Bus 12

BUS 12 Route

19 Minutes Driving Time; 8.1 Miles

	Stop	Number of Students Picked Up	
1	26 Beach St.	1	A
2	18 Beach St.	1	B
3	High St. @ Beach St.	3	C
	TURN LEFT ON HIGH ST.		
4	West Main @ High St.	4	D *Assumption Student
	TURN RIGHT ON W. MAIN		
5	146 W. Main	1	E
6	206 W. Main	2	
7	216 W. Main	1	
8	230 W. Main	2	F
9	238 W. Main	2	
10	246 W. Main	2	
11	294 W. Main	1	G
	TURN AROUND AT GLOVER RD.		
12	W. Main @ Glover Rd.	1	H
13	285 W. Main	1	
14	W. Main @ McGrath Rd.	1	
15	255 W. Main	2	I
	TURN RIGHT ON SINGLETARY RD.		
16	24 Singletary Rd.	1	J
	TURN BUS AROUND		
17	199 W. Main	1	
18	191 W. Main	3	K
19	181 W. Main	2	
20	177 W. Main	1	L
	TURN RIGHT ON SUTTON RD.		
21	2 Sutton Rd.	1	
22	10 Sutton Rd.	4	M
	TURN RIGHT ONTO HEMLOCK DR.		
23	1 Hemlock Dr.	1	N
24	11 Hemlock Dr.	2	O
	TURN LEFT ONTO SUTTON RD.		
25	Sutton Rd. @ Laurel Dr.	8	P
26	29 Sutton Rd.	1	Q
	TURN RIGHT ONTO W MAIN ST.		
	TURN RIGHT ONTO BURBANK ST.		
	TURN AROUND AT END OF BURBANK; NEAR TOWN LINE		
27	61 Burbank St.	5	R
28	7 Burbank St.	11	S
	TURN RIGHT ONTO W MAIN ST.		
29	W Main @ Rhodes St.	10	T
	TURN LEFT ONTO GOULD ST.		
	TURN LEFT ONTO ELMOOD ST.		
30	Shaw Elementry School		GOAL
31	Elmwood St. School		
32	Assumption School		
	Total Students	**76**	
	Capacity Percentage	**99%**	

Minutes	30 Second Times	Stops	Est. Time
19	25	29	725
			12.08333333
			31.08333333



8.10 Same Cost Calculations

COST DIFFERENTIAL

Assuming that the District is Purchasing 10 additional buses for one Tier and other buses are becoming two tier

- Daily Run Cost: $8,093.11
- $8,093.11 * 182 days = $1,472,946.02 for 2020
- $1,472,946.02 - $815,542 (current daily run cost) = $657,404.02 extra per year.

Increase in budget of 80.6%

* If an additional Special Education Bus needed to be purchased, Budget would increase by $1,633,289.84 or 80.9%.